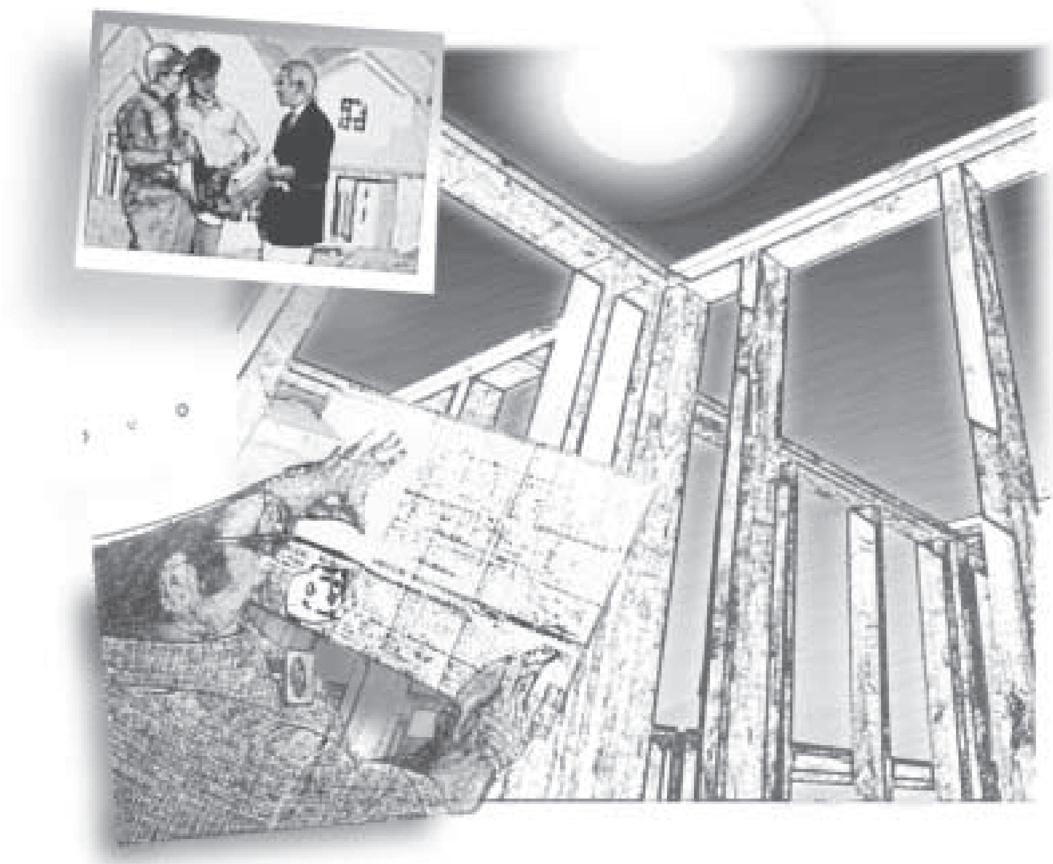
NOVEMBER 2002 DRAFT

2005 RESIDENTIAL

ACM MANUAL



CALIFORNIA ENERGY COMMISSION

CONSULTANT DRAFT REPORT

Workshop Draft
November 5, 2002
P400-03-003D
Contract 400-00-061

Gray Davis, Governor

Mary D. Nichols,

Secretary for Resources

CALIFORNIA ENERGY COMMISSION

William J. Keese
Chairman

Commissioners:

Robert Pernell
Arthur H. Rosenfeld
James D. Boyd
John L. Geesman

Steve Larson,
Executive Director

Valerie Hall,
Deputy Director
ENERGY EFFICIENCY and DEMAND ANALYSIS DIVISION

Mike Sloss,
Office Manager
Nonresidential Buildings Office

Bryan Alcorn, Commission Contract Manager
Bill Pennington, Commission Project Manager

Prepared by Eley Associates (Charles Eley)
San Francisco
Contract Number 400-00-061
November 5, 2002

Table of Contents

List of Tables

1. Overview

This Manual explains the requirements for approval of residential *Alternative Calculation Methods* (ACMs). Residential ACMs are used to demonstrate compliance with the performance approach to the efficiency standards for Low-Rise Residential Buildings as defined in the building energy efficiency standards of the State Building Code.

The approval procedure is one of self-testing and self-certification by the vendor of an ACM. The vendor conducts the specified tests, evaluates the results and certifies in writing that the ACM passes the tests. The California Energy Commission (Commission) will perform spot checks and may require additional tests to verify that the proposed ACM is suitable for compliance purposes. The vendor is required to develop a compliance supplement (program user manual) explaining how to use the program for showing compliance with the standards. The compliance supplement will also be checked by the Commission for accuracy and ease of use.

When energy analysis techniques are compared, there may be two basic sources of discrepancies: differences in user interpretation when entering the building specifications, and differences in the ACM's algorithms for estimating energy use. The approval tests in this manual are designed to minimize differences in interpretation by providing explicit detailed descriptions of the test buildings that must be analyzed.

This Manual is written as if all ACMs are computer programs. While this is generally true, there is nothing to prohibit other kinds of energy analysis methods from seeking ACM approval. The basic requirements for accuracy and reliability still apply.

1.1 Summary of ACM Changes

The ACM Approval Manual is updated with each major revision of the low-rise residential Standards. This manual is to be used with the 2001 Standards. The major changes between this manual and the 1998 manual are summarized below.

1.1.1 Modeling Assumptions

Several changes have been made to the way energy use is calculated in the public domain program, as summarized below.

- Interior Shading
- Space Conditioning System Efficiency (including a variety of assumptions such as air flow, refrigerant charge, fan wattage and efficiency adjusted for California’s outdoor operating temperatures)

1.1.2 Standard Design Definition

The definition of the standard design (the custom budget building) has been updated to correspond with the performance levels required by the 2001 Standards.

1.2 ACM Requirements

This chapter presents the general requirements for residential ACMs. Appropriate inputs for all modeling capabilities are discussed in Chapter 2.

1.2.1 Minimum Modeling Capabilities

Minimum modeling capabilities must be included in all ACMs. If a candidate ACM does not have all of these capabilities, then it cannot be approved for compliance. The minimum modeling capabilities are summarized below:

- Conduction gains and losses through opaque and fenestration surfaces.

- Infiltration gains and losses
- Solar gains through glazing including the effects of internal shading devices, external shading devices and fixed overhangs.
- Natural ventilation cooling and natural ventilation for Indoor Air Quality (IAQ).
- Mechanical Ventilation for IAQ.
- Thermal mass effects to dampen temperature swings.
- Space conditioning equipment efficiency and distribution systems.
- Water heating equipment efficiency and distribution systems.
- Radiant Barriers
- Cool Roofs

1.2.2 Optional Modeling Capabilities

Candidate ACMs may have more capabilities than the minimum required. ACMs can be approved for use with none, a few, or all of the optional capabilities. The following optional capabilities are recognized for residential ACMs:

- Raised floors with automatically operated crawl space vents.
- Zonal control or multi-zone modeling of the sleeping and living areas of the house.
- Attached sunspaces for collection and possible storage of heat for transfer to the main house.
- Exterior mass walls.
- Side Fin Shading.
- Combined hydronic space and water heating.
- Building additions.
- Solar water heating.
- Form 3 report generator.
- Gas-Fired Heat Pumps

Many of the optional modeling capabilities have been previously approved by the Commission through the exceptional methods process. The approval tests for optional modeling capabilities are included in Chapter 6. To determine how to apply for the Exceptional Method Application (EMA) to provide optional modeling capability, refer to Section 1.8, Page 5 of this Manual.

1.3 Application Checklist

The following is a checklist of all the items that must be included in an application package for ACMs. Some materials are required only for general purpose ACMs and are so indicated.

- *ACM Vendor Certification Statement.* A statement from the ACM vendor certifying the ACM, and, its reliability and accuracy when used for compliance purposes (see Appendix A, Page A-1).
- *Computer Run Summary Sheets.* Hard copy summary sheets of all the required computer runs (see Appendix A, Pages A-2 to A-12).
- *Computer Runs.* Copies of the computer runs specified in Chapters 5 and 6 of this Manual, including complete input and output files, on diskettes or in IBM-compatible computer readable form acceptable to the Commission to enable spot checks.

- *Compliance Supplement.* A copy of the Compliance Supplement discussed in Chapter 8. The Compliance Supplement and the ACM User's Manual may be combined into the same document.
- *Copy of the ACM.* A magnetic media copy of the ACM (in IBM-PC compatible, or other format agreed to by the Commission staff) for verification of analyses and random verification of compliance analyses. Weather data must be included.
- *Weather Data Documentation.* For those general purpose ACMs not using the standard Commission, full year, hourly weather data, a copy of the summarized weather data must be submitted. Documentation must be included on the method used to develop the summary weather data.
- *Application Fee.* An application fee of $1,000.00 (one thousand dollars) is required to cover costs of evaluating the application.

1.4 Types of Approval

This Manual addresses three types of ACM approval: full approval, streamlined approval of new program features, and amendments to full approvals.

1.4.1 Full Approval

Full approval is required when a candidate ACM has never been previously approved by the Commission, and/or when the ACM vendor makes changes to the executable program code or algorithms, or any other change that in any way affects the results. The Commission may also require that all ACMs be approved again when the standards are updated on the three-year cycle or whenever substantial revisions are made to the approval process, for instance, if new analysis capabilities come into widespread use, and the Commission declares them to be minimum capabilities for all ACMs.

When re-approval is necessary, the Commission will notify all ACM vendors of the timetable for renewal. There will also be a revised ACM Approval Manual published, with complete instructions for re-approval.

Full approval is required for all ACM changes, unless they qualify for the streamlined approval process or for an addendum, as discussed below.

1.4.2 Streamlined Approval

Certain types of changes may be made to approved residential ACMs through a streamlined procedure. Examples of changes that qualify for streamlined approval are modifications to the user interface or implementation on a different operating system as long as there are no changes to the executable program code that would in anyway affect the results.

If an ACM modification qualifies for streamlined approval, then the following procedure is followed:

- The ACM vendor prepares an addendum to the compliance supplement, when appropriate, describing the change to the ACM.
- The ACM vendor notifies the Commission by letter of the change. The letter must describe in detail the nature of the change and why it is being made. The notification letter shall be included in the Compliance Supplement.
- Provide the Commission with an updated copy of the ACM and include any new reports created by the ACM (or modifications in the standard reports).
- The Commission responds in 45 days. The Commission response may take several forms. The Commission may request additional information, refuse to approve the change or require that the ACM vendor make specific changes to either the Compliance Supplement addendum or the ACM.
- With Commission approval, the vendor may issue new copies of the ACM with the Compliance Supplement addendum and notify ACM users and building officials.

1.4.3 Amendments

An ACM approval must be amended when optional modeling capabilities are added. The vendor must provide the additional computer runs required for the optional modeling capability. It is not necessary to include computer runs previously submitted.

An amendment to an approved ACM must be accompanied by a cover letter explaining the type of amendment requested, and copies of other documents as necessary. All items on the application checklist should be submitted, when applicable. The timetable for approval of amendments is the same as for full approval.

1.4.4 When Approval Is Not Required

Changes that do not affect compliance with the Energy Efficiency Standards for Residential Buildings do not require full or streamlined approval. However, the ACM vendor must notify the Commission and provide the Commission with an updated copy of the program and user manual. Reapproval is required for any ACM program change that affects the energy use calculations for compliance, the modeling capabilities for compliance, the format and/or content of compliance forms, or any other change which would affect a building's compliance with the Standards. Any questions regarding applicable approval procedures should be directed to the Commission.

1.5 Challenges

Building officials, program users, program vendors or other interested parties may challenge any residential ACM approval. If any interested party believes that a compliance program , an algorithm, or method of calculation used in a compliance program, a particular capability or other aspect of a program provides inaccurate results, the party may challenge the program . (See Section Decertification of ACMs, for a description of the process for a challenge.)

1.6 Decertification of ACMs

The Commission may *decertify* (rescind approval of) an alternative calculation method through various means:

- All ACMs are decertified when the standards undergo substantial changes, which usually occur every three years.
- Any ACM can be decertified by a letter from the ACM vendor requesting that a particular version (or versions) of the ACM be decertified. The decertification request must briefly describe the nature of the program errors or "bugs" which justify the need for decertification.
- Any "initiating party" may commence a procedure to decertify an ACM according to the steps outlined below. The intent is to include a means whereby serious program errors, flawed numeric results, improper forms and/or incorrect program documentation not discovered in the certification process can be verified, and use of the particular ACM version discontinued. In this process, there is ample opportunity for the Commission, the ACM vendor and all interested parties to evaluate any alleged errors in the ACM program.

Following is a description of the process for challenging an ACM or initiating a decertification procedure:

1. Any party may initiate a review of an ACM's approval by sending a written communication to the Commission's Executive Director. (The Commission may be the initiating party for this type of review by noticing the availability of the same information listed here.)

   The initiating party shall:

   (a) State the name of the ACM and the program version number(s) which contain the alleged errors;

   (b) Identify concisely the nature of the alleged errors in the ACM which require review;

   (c) Explain why the alleged errors are serious enough in their effect on analyzing buildings for compliance to justify a decertification procedure; and,

(d) Include appropriate data on IBM PC compatible floppy diskettes and/or information sufficient to evaluate the alleged errors.

2. The Executive Director shall make a copy or copies of the initial written communication available to the ACM vendor and interested parties within 30 days.
3. Within 75 days of receipt of the written communication, the Executive Director may request any additional information needed to evaluate the alleged ACM errors from the party who initiated the decertification review process. If the additional information is incomplete, this procedure will be delayed until the initiating party submits complete information.
4. Within 75 days of receipt of the initial written communication, the Executive Director may convene a workshop to gather additional information from the initiating party, the ACM vendor and interested parties. All parties will have 15 days after the workshop to submit additional information regarding the alleged program errors.
5. Within 90 days after the Executive Director receives the application or within 30 days after receipt of complete additional information requested of the initiating party, whichever is later, the Executive Director shall either:

   (a) Determine that the ACM need not be decertified; or,

   (b) Submit to the Commission a written recommendation that the ACM be decertified.
6. The initial written communication, all other relevant written materials and the Executive Director's recommendation shall be placed on the consent calendar and considered at the next business meeting after submission of the recommendation. The matter may be removed from the consent calendar at the request of any person.
7. If the Commission approves the ACM decertification, it shall take effect 60 days later. During the first 30 days of the 60 day period, the Executive Director shall send out a Notice to Building Officials and Interested Parties announcing the decertification.

All initiating parties have the burden of proof to establish that the review of alleged ACM errors should be granted. The decertification process may be terminated at any time by mutual written consent of the initiating party and the Executive Director.

As a practical matter, the ACM vendor may use the 180- to 210-day period outlined here to update the ACM program, get it reapproved by the Commission, and release a revised version that does not contain the bugs initially brought to the attention of the Commission. Sometimes the ACM vendor may wish to be the initiating party to ensure that a faulty program version is taken off the market.

1.7 Alternative ACM Tests

This Manual provides tests to verify that ACMs are accurate. These tests are provided in Chapters 5 and 6 of the Manual. An ACM vendor may propose alternate tests when the vendor believes that one or more of the standard tests are not appropriate for the ACM. Alternate tests will be evaluated by the Commission and will be accepted if they are considered reasonable. If accepted, the alternate test(s) will be added to this manual as an addendum and the alternate test(s) will be available for use by all ACMs. The alternate test will coexist with the standard test presented in this Manual until the Manual is revised. When a new version of this Manual is produced, the alternative test may be substituted for the current test or may continue to coexist with the original test.

1.8 Approval of New Exceptional Methods

The Commission may approve new exceptional methods. Exceptional methods are special modeling capabilities or calculation methods necessary to recognize building features that cannot be adequately modeled with existing ACMs. When an Exceptional Method is approved, a new optional capabilities test may be approved as part of the process. Exceptional Methods do not necessarily produce optional capabilities for ACMs. For instance, radiant heating systems are recognized by an adjusted equipment efficiency that may be used directly in ACMs or other compliance methods. To be approved for the new optional capability, vendors must amend their ACM approval.

Even if an ACM already incorporates the Exceptional Method, the vendor must receive approval to use the Exceptional Method in the compliance process. The ACM vendor must demonstrate that the ACM automatically uses the correct fixed and restricted inputs for the Exceptional Method and that the standard reports identify the building feature(s) recognized by the Exceptional Method. Additionally, the ACM compliance supplement must be updated, referencing the use of the new Exceptional Method.

To receive a copy of the Exceptional Method contact the Residential Office at (916) 654-4064.

2. Standard Reports

For consistency and ease of enforcement, the manner in which building features are reported by ACMs must be standardized. This section of the ACM Approval manual describes the required standard reports. All residential ACMs must automatically produce compliance reports in the Commission-prescribed format specified in the following sections of this Manual. These *Standard Reports* are required to enable building officials to evaluate the results from ACMs without having to learn each computer program. Included in every compliance package will be reports CF-1R and C-2R, which are described in detail below.

Both the CF-1R and the C-2R must have two highly visible sections, one for special features and modeling assumptions and a second for features requiring verification by approved home energy rating system (HERS) providers. These two sections serve as “punchlists” for special consideration during compliance verification by the local building department. Items listed in the *Special Features and Modeling Assumptions* section indicate the use for compliance of unusual features or assumptions, and call for special care by the local building department. Items listed in the HERS Required Verification section are for features that rely on diagnostic testing or independent verification by HERS raters under the supervision of Commission-approved HERS providers to insure proper field installation in addition to local building department inspection.

Only user inputs are described and included in the standard reports. The fixed and restricted inputs are not included since ACMs must be designed so that the fixed and restricted inputs and default values in the absence of specific user input are automatically used when the program is used for compliance.

For compliance forms, the structure of the Standard Reports described in the subsequent sections should be followed as closely as possible. The reports are divided into tabular listings that have a title, column headings and data entries. The data entries shown in the listings that appear in this manual are typical values and are included only to illustrate the report format; they are not default values and cannot be assumed to be in compliance with the standards. The specification of the category or type of data expected in each field is provided in the list of definitions associated with each column heading. The type of data entries will be one of the following:

- text: A variable-length text field input by the user.
- recommended descriptor: An abbreviation or short name from lists or tables of permissible types provided within this manual (e.g., LgStoGas). Only types found in these lists or tables may be used. Different descriptors may be used by the ACM as long as they are reasonable descriptors for the list entry item and are not misleading. In some cases where the descriptor is a short complete word, the descriptors are prescribed and must be used. Even for prescribed descriptors some discretion is allowed. For example, for tables with long rows Y may be used for the prescribed descriptor Yes. User-defined descriptors may NOT be used but rather must be automatically assigned by the ACM based upon user input. For example, UWALL01 may be assigned by the ACM to the first user-defined wall type.
- filename.ext: The name of the input or output file
- dimensions or units of measure, such as "hr-ft2-F /Btu", ft2, etc.
- Num: A cardinal or ordinal number.

Modifications will be approved by the Commission when they are necessary because of conceptual differences between ACMs or because of special modeling features. The categories of information represented in the tables and the standard headings must not be changed. Additional columns or additional tables may be added when necessary and column headings may be abbreviated, and reports may be reformatted with different character spacing, line spacing, row heights or column widths to permit better readability or paper conservation. ACMs may also provide additional customized information at the bottom of the standard reports, separated from the standard report by a line.

Some of the tables in the Standard Reports are not applicable for all buildings. When a table is not applicable for a particular building, it should be omitted. When one of the standard tables is included, all the columns should be included (although column width may be reduced), even if some of the information in the columns is not applicable to the proposed design.

The Standard Reports are designed to accommodate the optional modeling capabilities included in this manual. Approval of additional optional modeling capabilities may require modification of the standard report format.

2.1 Certificate of Compliance (CF-1R)

The Certificate of Compliance (report CF-1R) is the first standard report that must be produced. The Certificate of Compliance is required by the Administrative Requirements (Title 24, Section 10).

Heading. The following heading shall appear on the first page.

CERTIFICATE OF COMPLIANCE: RESIDENTIAL		Page 1 of 2 CF-1R
Project Title	Filename:	Date:
Project Address	Run Title:	<runcode>
Documentation Author		<initiation time>
Telephone		Building Permit #
Compliance Method		Plan Check / Date
Location/Climate Zone		Field Check/ Date

The Filename, Run Title, Runcode, and Initiation Time need not appear in the header as shown above but must appear as part of the header information for all pages of the Certificate of Compliance.

Subsequent pages shall have the following heading.

CERTIFICATE OF COMPLIANCE: RESIDENTIAL		Page 2 of 2 CF-1R
Project Title	Filename:	Date:
	Run Title:	<runcode/initiation time>

- Project Title, Date, Project Address, Documentation Author and Telephone, and Climate Zone (text): Display user inputs for these fields.
- Filename (filename.ext): The filename of the input file used to generate the compliance form.
- Compliance Method (text): The Alternative Calculation Method program name and version number (e.g., CALRES2 v2.01)
- <Runcode/Initiation Time> (alphanumeric text): A unique runcode designation generated automatically by the ACM to identify the specific run. This number and the initiation time changes with each run initiated by the user even though the filename and Run Title may remain the same. The initiation time is the time (including the hour and minute) that the compliance run was initiated by the user.
- Run Title (text): Optional user input item. Use for commentary or description of unique characteristics of a particular run.

General Information. This listing in the Certificate of Compliance follows the first page heading on both the CF-1R and the CF2-R and provides basic information about the building. The items and information listed on the Certificate of Compliance are identical to some of the items and information found in the Computer Method Summary (C-2R). A description of these data elements is given later in this chapter.

GENERAL INFORMATION

Conditioned Floor Area:	1384 ft^2
Average Ceiling Height	10.2 ft.
Building Type:	Single Family Detached
Building Front Orientation:	15 deg (North)
Glazing Area as % of Floor Area	14.4%
Average Fenestration U-Value	0.52
Average Fenestration SHGC	0.60
Number of Stories	2
Number of Dwelling Units:	1
Floor Construction Type:	Raised Floor

Building Insulation. This listing summarizes the insulation levels and conditions for the opaque surfaces of the building and slab perimeters. A separate row is to be provided for each unique condition. If a radiant barrier is used for a roof, the ACM is required to report this feature. The ACM may either add a column, titled "Radiant Barrier" and place the word "Yes" in the corresponding row, or the words "Radiant Barrier" are to be automatically placed in the Location/Comments field in the row associated with the roof surface having the radiant barrier."

Metal-framed walls are reported in the frame type column. The use of metal-framed walls must be reported in the *Special Features and Modeling Assumptions* listing since metal framing reduces the effective R-value of cavity insulation by short circuiting heat flow.

BUILDING INSULATION

Component Type	Frame Type	Cavity Insulation R-value	Sheathing Insulation R-value	Total R-value	Assembly U-value	Location/Comments
Wall	Wd2x4@16"oc	R-11	R-4	15.38	0.065	typical
Wall	Mtl2x4@16"oc	R-13	R-7	12.20	0.082	at garage
Mass Wall	n/a	R-5	R-0	6.29	0.159	Foundation
Roof	Wd2x6@24"oc	R-38	R-0	38.5	0.026	Attic w/Radiant Barrier
Roof	Wd2x10@24"oc	R-30	R-0	29.41	0.034	Vaulted Ceiling
Door	n/a	R-0	R-0	3.03	0.33	
Floor	Wd2x12@24"oc	R-19	R-0	27.03	0.037	crawl space
Floor	Wd2x10@16"oc	R-19	R-0	20.83	0.048	Over garage
Slab Perimeter	n/a	R-7	n/a			F2 = 0.76 uninsulated

- *Component Type.* Possible types are wall, mass wall, door, ceiling or roof, floor over crawl space, exposed floor, slab perimeter, etc.
- *Frame Type.* Framing information shall include framing material [wood (*Wd*) or metal (*Mtl*) alternatively steel (*Stl*) or aluminum (*Alu*)], the nominal size of framing members [e.g. 2x4 for nominal 2" x 4"], and their nominal spacing [@16"oc for "at 16 inches on center"]. Metal framing is presumed to be steel framing unless otherwise coded.
- Cavity *Insul R-value.* The R-value of the cavity insulation alone, not including framing effects, dry wall, air films, etc. If no insulation is proposed, the response may be "none".

- *Total R-value.* The number one divided by the *Assembly U-Value* (the inverse of the *Assembly U-Value* or $1/U_{assembly}$) rounded to two digits to the right of the decimal point.
- *Sheathing Insul. R-value:* The sum total R-value of continuous insulation layers which are not penetrated by framing members. These are for layers used specifically for insulation (R-2 or greater) and do not include interior or exterior finish materials such as drywall or exterior siding layers unless they have significant thermal resistance. For slabs-on-grade, report the R-value of slab edge insulation.
- *Assembly U-value*. The U-value for the assembly, including framing effects. Calculated U-values are rounded to three digits to the right of the decimal point. (U-values are calculated using standard engineering principles as documented in the Glossary, Appendix G of the *Residential Manual*[1] under *R-Value*)
- *Location/Comments.* A description of where the component is located or other relevant information.

Floors. This listing summarizes floor types and surface areas. The ACM shall use this information to determine the thermal mass for the Standard Design and the default thermal mass for the Proposed Design. This listing must include all conditioned floor area and may include listings of unconditioned floor types and areas.

FLOOR TYPES AND AREAS

Construction Type	Area (ft^2)	Conditioned?	Location/Description
Slab	1086	Yes	1st Floor
Slab	226	No	Garage
NonSlab	675	Yes	2nd Floor

- *Construction Type:* The construction type of the floor. Construction type is either *Slab or NonSlab Floor.* A *Slab* floor includes slab-on-grade floors and raised slab floors with conditioned space above and unconditioned space below. Raised slab floors with conditioned space above and below are considered *NonSlab* floors for this categorization. Floors with unconditioned space above may be either *Slab* or *NonSlab*.
- *Area (ft^2).* The area of the mass element in square feet.
- *Conditioned?*: The conditioning status of the air immediately above the floor. *Yes* indicates that the air is conditioned and *No* indicates that the air above this part of the floor is unconditioned. An ACM may exclude this column if it is clear to the user that all entries for floor area are for conditioned floor area only. If the ACM excludes this output column, the ACM must assign all user entered floor areas as conditioned floor areas and spaces with unconditioned floor areas such as sunspaces shall not be modeled.
- *Location/Description.* A description of the location of the floor.

Fenestration Surfaces. The term "fenestration" is used to refer to an assembly of components consisting of frame and glass or glazing materials. According to the standards, fenestration includes “any transparent or translucent material plus frame, mullions, and dividers, in the envelope of a building.” Fenestration surfaces include windows, skylights and glazing in doors or other transparent or translucent surfaces. This listing reports information about each fenestration surface. One row is to be included in the listing for each unique fenestration condition. When compliance is for all orientations, the building facade orientations shall be reported for the case with the “front” facing north or the orientation shall be reported as “*Any*”, and the *Special Features and Modeling Assumptions* listings must also indicate that compliance is for all orientations.

[1] 2001 Residential Manual, California Energy Commission Publication P400-00-029.

FENESTRATION SURFACES

Fenestration #/Type/Orien	Orien-tation	Area (ft^2)	Fenestration U-factor	Fenestration SHGC	Exterior Shading Att.	Over-hang /Fins
1 Wdw Front	N	10	0.65	0.70		None
2 Wdw Front	NW	40	0.65	0.60		None
3 Wdw Front	N	8	1.23	1.23	NA	None
4 Wdw Left	W	110	0.65	0.65	Shade-screen	None
5 Wdw Back	S	50	0.65	0.65		Ovhg
6 Wdw Back	S	8	1.23	1.23		None
7 Wdw Right	E	85	0.65	0.65		None
8 Sky Back	S	8	1.23	1.23		None
9 Sky Horz	NA	22	1.23	1.23		None

- *Fenestration Surface: Num/Type/Loc (#/text/prescribed descriptor). Num* is a unique number assigned by the user to each fenestration item in the fenestration surfaces list (see Computer Method Summary; C-2R). The type is Wdw (window) Dr (door) or Sky (skylight). *Loc* is the location of the surface with respect to the front of the building (Front, Back, Left, Right orNA).
- *Orientation* (prescribed descriptor) is reported here as the nearest 22.5° compass point in parenthesis (N, NNE, NE, ENE etc.). *Orientation* may also be reported to the nearest degree (0°-360°). When compliance is for all orientations, orientation may be listed as *All* or only the *Loc* need be reported or *Orientation* may be reported with Front facing North.
- *Area (ft^2).* The rough frame area of the fenestration in square feet.
- *U-factor*. The rated U-factor of the fenestration product, in Btu/h-ft^2-°F, including air films. Calculated fenestration U-factors are rounded and reported to 2 digits to the right of the decimal.
- *Fenestration SHGC:* The Solar Heat Gain Coefficient (SHGC) for this fenestration system typically the glazing plus the frame. This value corresponds to the rated value reported on a Commission-approved label, a Commission default value reported on a manufacturer's label, or a Commission default value for a carpenter's window.
- *Exterior Shading Att.:* A verbal description of the exterior shading attachment, when applicable. Only a limited number of shading attachments may be used for shading credit in the performance approach. The exterior shading attachments and their allowed SHGCs are listed in Table R2-1 - Allowed Exterior Shading Devices and Recommended Descriptors below:
- "Standard" (Default Bug Screen) or " " must automatically appear when no special exterior shading device is included in the building plans. The standard design assumes that Standard or default partial bugscreen coverage credit is used for all windows. The proposed design assumes that Standard is used for all windows unless other exterior shading attachments are specified. Standard credit has been reduced to account for the fact that bugscreens will only cover a portion of all windows in a house or residence. A user claiming credit for any ordinary bugscreens must use Standard as the input for the exterior shading device modeled.

Table R2-1 - Allowed Exterior Shading Devices and Recommended Descriptors

Recommended Descriptor	**Exterior Shading Device Reference**	**Solar Heat Gain Coefficient**
Standard	Bugscreens or No Shading - Default Bug Screens are modeled.	0.76
WvnScrn	Woven SunScreen (SC<0.35)	0.30
LvrScrn	Louvered Sunscreen	0.27
LSASnScrn	LSA Sunscreen	0.13
RlDwnAwng	Roll-down Awning	0.13
RlDwnBlnds	Roll -down Blinds or Slats	0.13
None 1	For skylights only - No exterior shading	1.00
Note 1: None is the default for fenestration tilted less than 60 degrees from horizontal (skylights) and is only allowed for fenestration tilted less than 60 degrees from horizontal (skylights)., i.e. None is not an exterior shading option for ordinary vertical windows.		

- *Overhangs/Fins:* An indication of whether or not the fenestration is shaded by overhangs or fins [*Ovhg, Fins, Both, None]*

Thermal Mass. This listing summarizes thermal mass elements in the proposed design. Note that ACMs must require the input of conditioned slab floor area and the conditioned nonslab floor area prior to the entry of special thermal mass features. These two areas determine the thermal mass for the Standard Design and the default thermal mass for the Proposed Design. The specific thermal mass for the proposed design is ONLY modeled if the thermal mass for the proposed design exceeds a specific threshold, otherwise the default thermal mass is modeled for both the Proposed and Standard Designs (See Sections 3.6 and 3.7 for more details). This *Thermal Mass* listing **must not** be reported unless the Proposed Design's thermal mass exceeds the mass credit threshold. When the thermal mass in the *Proposed Design* is greater than the threshold mass it must be reported in this format and it **must automatically** be reported in the *Special Features and Modeling Assumptions* listing and independently verified by the local enforcement agency.

THERMAL MASS

Type/Covering	Area (ft^2)	Thickness	Location/Description
Slab Exposed	120	3.5 in	Kitchen entry
Slab Covered	250	3.5 in	Kitchen dining
Nonslab	980	0	All Other
Tile	34	0.5 in	Bath

- *Type/Covering.* The type of mass and the surface condition (exposed or covered). The types described in the *Residential Manual* Glossary may be used.
- *Area (ft^2).* The area of the mass element in square feet.
- *Thickness.* The mass thickness in inches.
- *Location/Description.* A verbal description of the location of the mass or other special features.

Infiltration/Ventilation. This listing is only produced when the applicant has used reduced infiltration measures or mechanical ventilation measures to improve the overall energy efficiency of the Proposed Design while maintaining adequate air quality. The use of reduced infiltration requires diagnostic blowerdoor testing by a certified HERS rater to verify the modeled reduced leakage area and to ensure minimum infiltration/ventilation rates are achieved. Relevant information regarding infiltration and ventilation must be reported in the *HERS Required Verification* listings on the CF-1R and the C-2R. The listings must indicate that diagnostic blower door testing must be performed as specified in ASTM E 779-87 (Reapproved 1992), *Standard Test Method for Determining Air Leakage Rate by Fan Pressurization*. This listings must also report the target $CFM50_H$ required for the blowerdoor test to achieve the modeled SLA and the minimum $CFM50_H$

(corresponding to an SLA of 1.5) allowed to avoid backdraft problems. This minimum allowed value is considered by the Commission to be “unusually tight” per the requirements of the Uniform Mechanical Code.

When the target $CFM50_H$ of the *Proposed Design* is below the value corresponding to an SLA of 3.0, mechanical ventilation with a minimum capacity of 0.047 CFM per square foot of conditioned floor area is required. This requirement for mechanical ventilation and minimum capacity must be reported in the *HERS Required Verification* and the *Special Features and Modeling Assumptions* listings of the CF-1R and C-2R. Also, the *HERS Required Verification* listings must state that when the measured $CFM50_H$ is less than the minimum allowed value, corrective action must be taken to either intentionally increase the infiltration or provide for mechanical supply ventilation adequate to maintain the residence at a pressure greater than -5 pascals relative to the outside average air pressure with other continuous ventilation fans operating. Mechanical ventilation may also be used in conjunction with reduced infiltration to achieve even greater energy savings. When mechanical ventilation is part of the Proposed Design the exhaust and supply fan wattages must be reported in this listing and the *HERS Required Verification* listings. Whenever mechanical ventilation is modeled by the user or required by modeling an SLA of 3.0 or less, the mechanical ventilation capacity selected by the user must be greater than or equal to 0.047 cfm per square foot of conditioned floor area to be modeled by an approved ACM. If the user enters a volumetric capacity that is less than 0.047 cfm/ft^2, the ACM must indicate an input error to the user and block compliance output.

When reduced infiltration or mechanical ventilation is modeled, the *Special Features and Modeling Assumptions* listings must include a statement that the homeowner’s manual provided by the builder to the homeowner must include instructions that describe how to use the operable windows or mechanical ventilation to provide for proper ventilation.

INFILTRATION/VENTILATION DETAILS *(Example Listing)*

Blower Door Leakage Target ($CFM50_H$/SLA)	Blower Door Leakage Minimum ($CFM50_H$/SLA)	Vent. Fan CFM (Supply/Exhaust)	Mechanical Vent Fans (Watts) [Supply/Exhaust]
1250/2.9	586/1.5	200/300	*50/75*

- *Blower Door Leakage Target ($CFM50_H$/SLA):* The measured blower door leakage in cfm at 50 pascals of pressurization and its equivalent Specific Leakage Area (SLA) value.
- *Blower Door Leakage Minimum ($CFM50_H$/SLA):* The backdraft limit for the blower door leakage test which corresponds to a Specific Leakage Area (SLA) of 1.5 which is considered to be “unusually tight” and must satisfy the Uniform Mechanical Code requirements for “unusually tight” construction. The ACM must report in the *HERS Required Verification* listings that the Commission considers this minimum CFM and the corresponding SLA of 1.5 or less to be “unusually tight” per the Uniform Mechanical Code. In the sample listing given above a 1600 square foot house and the SLA lower limit of 1.5 is used to get the *Blower Door Leakage Minimum* shown.
- *Vent. (Ventilation) Fans (CFM):[Supply/Exhaust]* The total volumetric capacity of supply fans and exhaust fans listed separately, separated by a slash (or reported in separate columns). The balanced portion of mechanical ventilation is the smaller of these two numbers while the unbalanced portion is the difference between these two numbers. These values are reported in cubic feet per minute.
- *Mechanical Vent. (Ventilation) Fans (Watts) [Supply/Exhaust]:* The total power consumption of the supply ventilation fans and the total power consumption of the exhaust ventilation fans in watts.

HVAC Systems. This listing provides data on the heating and cooling systems in the building. These data are identical to those in the Computer Method Summary (Report C-2R) under "HVAC Systems" described on Page 35

HVAC SYSTEMS

System Name	System Type	Refrigerant Charge ~~and Airflow~~	Minimum Equipment Efficiency	Distribution Type and Location	Duct R-value
Zone=Living					
LowerHeat	GasFurnace	N/A	0.78 AFUE	DuctsCrawl	~~4.2~~8
LowerAC	AirCond-Split	Yes	10.0 SEER	DuctsCrawl	~~4.2~~8
Maximum Allowable Cooling Capacity 23293 Btu/hr Adequate Airflow Level @400 cfm/ton: 776 cfm					
Zone=Sleep					
UpperHeat	Electric	N/A	1.00 COP	Baseboard	
UpperAC	AirCond-Split	No	10.0 SEER	DuctsAttic	~~4.2~~8
Maximum Allowable Cooling Capacity 15730 Btu/hr Adequate Airflow Level @400 cfm/ton: 524 cfm					

- *System Name (text):* A unique name for the HVAC system
- *System Equipment (recommended descriptor):* The type of HVAC equipment. This is specified separately from the distribution type.

  Permissible equipment types: Listed in Table R2-2 - HVAC Heating Equipment Descriptors and Table R2-3 - HVAC Cooling Equipment Descriptors.

  In the case of *CombHydro* heating, the name of the water heating system should be identified in the previous column. When the proposed house is not air conditioned, the entry should be *NoCooling*. If more than one type of equipment is specified, each must be listed on separate rows.
- *Refrigerant Charge ~~and Airflow~~:* Whether the refrigerant charge ~~and airflow~~ is verified or a thermostatic expansion valve is included for ducted central systems. The choices are ‘yes’ or ‘no’ where “yes” means that either refrigerant charge ~~and airflow are~~ is verified or a TXV is installed. Only split system equipment (*SplitAirCond and SplitHeatPump)* can be modeled with refrigerant charge ~~and airflow~~ verification. Six equipment types can be modeled with a TXV. They are: *SplitAirCond, PkgAirCond, LrgPkgAirCond, SplitHeatPump, PkgHeatPump, LrgPkgHeatPump.* See Table R2-3 - HVAC Cooling Equipment Descriptors for a description of equipment.

Table R2-2 - HVAC Heating Equipment Descriptors

Recommended Descriptor	Heating Equipment Reference
CntrlFurnace	Gas- or oil-fired central furnaces, propane furnaces or heating equipment considered equivalent to a gas-fired central furnace, such as wood stoves that qualify for the wood heat exceptional method. Gas fan-type central furnaces have a minimum AFUE=78%. Distribution can be gravity flow or use any of the ducted systems. [Efficiency Metric: AFUE]
Heater	Non-central gas- or oil-fired space heaters, such as wall heaters floor heaters or unit heater. Equipment has varying efficiency requirements. Distribution is ductless and may be gravity flow or fan-forced.. Can refer to floor furnaces and wall heaters within the description field for CntrlFurnaces, [Efficiency Metric: AFUE]
Boiler	Gas or oil boilers. Distribution systems can be Radiant, Baseboard or any of the ducted systems. Boiler may be specified for dedicated hydronic systems. Systems in which the boiler provides space heating and fires an indirect gas water heater (IndGas) may be listed as Boiler/CombHydro Boiler and must be listed under "Equipment Type" in the HVAC Systems listing. [Efficiency Metric: AFUE]
SplitHeatPump	Heating side of central split system heat pump heating systems. Distribution system must be one of the ducted systems. [Efficiency Metric: HSPF]
PkgHeatPump	Heating side of central packaged heat pump systems. Central packaged heat pumps are heat pumps in which the blower, coils and compressor are contained in a single package, powered by single phase electric current, air cooled, rated below 65,000 Btuh. Distribution system must be one of the ducted systems. [Efficiency Metric: HSPF]
LrgPkgHeatPump	Heating side of large packaged units rated at or above 65,000 Btu/hr (heating mode). Distribution system must be one of the ducted systems. These include water source and ground source heat pumps. [Efficiency Metric: COP]
GasHeatPump	Heating side of a gas-fired heat pump. Two efficiencies, a COP for the gas portion and a COP for the electric portion. Descriptors expressed as COPheatinggas/COPheatingelectric.
RoomHeatPump	Heating side of non-central room air conditioning systems. These include small ductless split system heat pump units and packaged terminal (commonly called "through-the-wall") units. Distribution system must be DuctIndoor. [Efficiency Metric: COP]
Electric	All electric heating systems other than space conditioning heat pumps. Included are electric resistance heaters, electric boilers and storage water heat pumps (air-water) (StoHP). Distribution system can be Radiant, Baseboard or any of the ducted systems. [Efficiency Metric: HSPF]
CombHydro	Water heating system can be storage gas (StoGas, LgStoGas), storage electric (StoElec) or heat pump water heaters (StoHP). Distribution systems can be Radiant, Baseboard, or any of the ducted systems and can be used with any of the terminal units (FanCoil, RadiantFlr, Baseboard, and FanConv).

Table R2-3 - HVAC Cooling Equipment Descriptors

Recommended Descriptor	**Cooling Equipment Reference**
NoCooling	Entered when the proposed building is not air conditioned or when cooling is optional (to be installed at some future date). Both the Standard Design equivalent building and the proposed design use the same default system (refer to sections 3 and 4). [Efficiency Metric: SEER]
SplitAirCond	Split air conditioning systems. Distribution system must be one of the ducted systems. [Efficiency Metric: SEER]
PkgAirCond	Central packaged air conditioning systems less than 65,000 Btuh cooling capacity. Distribution system must be one of the ducted systems. [Efficiency Metric: SEER]
LrgPkgAirCond	Large packaged air conditioning systems rated at or above 65,000 Btu/hr (cooling capacity). Distribution system must be one of the ducted systems. [Efficiency Metric: EER]
RoomAirCond	Non-central room air conditioning cooling systems. These include small ductless split-system air conditioning units and packaged terminal (commonly called □through-the-wall□) air conditioning units. Distribution system must be DuctIndoor. [Efficiency Metric: EER]
SplitHeatPump	Cooling side of split heat pump systems. Distribution system must be one of the ducted systems. [Efficiency Metric: SEER<65,000 Btu/hr EER>65,000 Btu/hr]
PkgHeatPump	Cooling side of central single-packaged heat pump systems with a cooling capacity less than 65,000 Btuh. Distribution system must be one of the ducted systems. [Efficiency Metric: SEER]
LrgPkgHeatPump	Cooling side of large packaged heat pump systems rated at or above 65,000 Btu/hr (cooling capacity). Distribution system must be one of the ducted systems. [Efficiency Metric: EER]
GasCooling	Cooling side of a gas-fired heat pump or gas-fired air conditioner. Two efficiencies, a COP for the gas portion and a COP for the electric portion. Descriptors expressed as COPcoolingas/COPcoolingelectric.
RoomHeatPump	Cooling side of non-central, room heat pump systems. These include small ductless split-system air conditioning units and packaged terminal (commonly called □through-the-wall□) units. Distribution system must be DuctIndoor. [Efficiency Metric: EER]
EvapDirect	Direct evaporative cooling systems. The SEER is set to 11.0. The default distribution system location is DuctAttic; evaporative cooler duct insulation requirements are the same as those for air conditioner ducts. [Efficiency Metric: SEER]
EvapIndirDirect	Indirect-direct evaporative cooling systems. The SEER is set to 13.0. The default distribution system location is DuctAttic; evaporative cooler duct insulation requirements are the same as those for air conditioner ducts. [Efficiency Metric: SEER]

- *Minimum Equipment Efficiency/Method (fraction/recommended descriptor):* The minimum equipment efficiency needed for compliance along with the applicable method.

  Permissible Methods: *AFUE* for furnaces and boilers, *HSPF* for electric heating equipment, *SEER* for heat pumps (cooling) and central air conditioners, and *RE* for water heaters.

  If equipment type is *Electric* (other than heat pump), an HSPF of 3.413 should be entered, except for radiant systems which may use an HSPF of 3.55.

- *Distribution Type and Location (recommended descriptor):*

  Permissible entries: Listed in Table R2-4

Table R2-4 - HVAC Distribution Type and Location Descriptors

Recommended Descriptors	HVAC Distribution Type and Location Reference
Ducted Systems	Fan-powered, ducted distribution systems that can be used with most heating or cooling systems. When ducted systems are used with furnaces, boilers, or combined hydronic/water heating systems the electricity used by the fan shall be calculated using the methods described later in this manual. R-value must be specified in "Duct R-value" column when a ducted system is specified
DuctsAttic	Ducts located overhead in the unconditioned attic space
DuctsCrawl	Ducts located underfloor in the unconditioned crawl space
DuctsCVC	Ducts located underfloor in a controlled ventilation crawl space
DuctsGarage	Ducts located in an unconditioned garage space.
DuctsBasemt	Ducts located in an unconditioned basement space
DuctsInEx12	Ducts located within the conditioned floor space except for less than 12 lineal feet of duct, typically an HVAC unit in the garage mounted on return box with all other ducts in conditioned space.
DuctsInAll	HVAC unit or systems with all HVAC ducts located within the conditioned floor space, such as gas-fired wall furnaces. This category is used also for systems such as wall furnaces having a fan.
DuctsOutdoor	Ducts located in exposed locations outdoors.
Ductless Systems	Ductless radiant or warm/cold air systems using fan-forced or natural air convection and hydronic systems relying upon circulation pumps and fan-forced or natural air convection, and
Furnaces	Heating equipment such as wall and floor furnaces
Radiant	Radiant electric panels or fanless systems used with a boiler, electric or heat pump water heater, or combined hydronic heating equipment.
Baseboard	Electric baseboards or hydronic baseboard finned-tube natural convection systems

- *Diagnostic Duct Leakage.* If diagnostic duct leakage is specified by the user, the requirement for diagnostic testing shall be reported in the *HERS Required Verification* listings on the CF-1R and C-2R.

- *Duct R-value(hr-ft2̃-F/Btu).* The installed R-value for duct insulation. The minimum value is 4.2, which is required by the mandatory measures section.

When the modeled duct R-value is larger than 4.2, the ACM must report the modeled R-value in this listing and must specify this higher duct R-value in the *Special Features and Modeling Assumptions* listings.

The modeled R-value cannot be less than 4.2 °F-ft2-hr/Btu unless an existing building and an existing HVAC distribution system is being modeled as part of an existing plus addition analysis. When duct R-value is less than 4.2 the *Special Features and Modeling Assumptions* listings must indicate that an existing building with an existing HVAC distribution system is being modeled as part of an existing plus addition analysis.

- *Maximum Allowable Cooling Capacity (Btu/hr).* The maximum allowable cooling capacity.
- *Adequate Airflow Level @ 400 cfm/ton.* The minimum airflow required to meet the adequate airflow criteria calculated at 400 cfm/ton.

HVAC Distribution Systems Misc. This listing details important information associated with the use of special HVAC distribution efficiency. The use of any of these features is considered to be special and must also be individually listed on the *HERS Required Verification* listing and individually verified.

HVAC DISTRIBUTION EFFICIENCY DETAILS *(Example Listing)*

System Name	Measured Duct Leakage Target (% of fan cfm / leakage cfm)1,2	Measured Duct Surface Area (ft2)	~~ACCA Manual D Design~~Adequate Air Flow	Fan CFM
Primary	6%/75.6	*150*	~~*Yes*~~*Yes*	1200
Bath	n/a	*None*	~~*No*~~*No*	*n/a*

Note 1: % of fan cfm is used when the HVAC system is installed at the time of testing and is based on a supply fan capacity of 400 cfm per ton of air conditioning capacity or 21.7 cfm per 1,000 Btus/hour of furnace capacity. When the HVAC is not installed or its capacity is not known the alternate leakage target reported is calculated from 6% of 0.70 cfm per square xxx foot of conditioned floor area for Climate Zones 8 to 15 and 0.50 cfm per square foot of conditioned floor area for the remaining Climate Zones. For an 1800 square foot house in Climate Zone 13 (example shown above) the maximum duct leakage when system capacity is unknown is 75.6 cfm at 25 pascals.

Note 2: The HERS Required Verification listings must include the information specified in Note 1 or the results of those calculations as the method of reporting the appropriate target values for the reduced duct leakage test.

- *System Name (text):* Descriptive name corresponding to a system name defined in the HVAC System listing.
- *Measured Duct Leakage Target (% of fan cfm/leakage cfm):* Reduced duct leakage has been modeled to determine seasonal duct efficiency. This credit requires site diagnostic testing by a certified HERS rater supervised by a Commission-approved HERS provider tested in accordance with the procedures in Appendix F. The test results must be less than 6% of fan cfm (derived from installed system capacity when present or from the default assumptions for duct efficiency calculations when the HVAC heating or cooling equipment is not installed) and reported by the HERS rater on a CF-6R form and verified by the local enforcement agency. The target duct leakage must be listed in the *HERS Required Verification* section.
- ~~*ACCA Manual D Design*~~ *Adequate Air Flow(prescribed descriptor: Yes* or *No)*: Indicates whether modeling credit for ~~ACCA Manual D duct design has been used~~adequate air flow has been used. When duct efficiency credit for ~~ACCA Manual D design~~ adequate air flow is claimed, the *HERS Required Verification and the Special Features and Modeling Assumptions* listings must specify that the ~~ACCA Manual D~~ duct design, layout, and calculations be submitted to the local enforcement agency and a certified HERS rater. The certified HERS rater shall verify the existence of ~~ACCA Manual D~~ the duct design layout and calculations, ~~and~~ verify that the field installation is consistent with this design and verify that adequate measured air flow is achieved.
- Measured Duct Surface Area (ft2): This item is applicable only if a design ~~the entry for ACCA Manual D Design is "Yes" and~~ documents the modeling of reduced duct surface area when a value other than na (not applicable) is reported. The HERS Required Verification listing must indicate that this total value and its subcomponent areas by location must be verified by a certified HERS rater. Moreover reduced duct ~~sizes~~ surface area must still preserve adequate air flow to receive duct efficiency credit. Consequently credit for reduced duct surface area also requires that the HERS rater measure and report HVAC supply fan flow to verify ~~that the manufacturer's specified~~ the fan flow, ~~consistent with the ACCA manual D design,~~ has not been impaired by reduced duct ~~sizes~~surface area. The *HERS Required Verification* listing must also indicate this requirement.

When *Measured Duct Surface Area* is specified the *HERS Verification Listings* must report the supply duct surface area in each of four locations: *Attic/Outside, Crawlspace, Basement, Garage.* This listing must also report whether or not the basement where the ducts are located is conditioned or not.

Water Heating Systems. This listing provides information on the water heating systems used in the building and is identical to information in the listings of the Computer Method Summary (C-2R) described on Page 37. Information concerning auxiliary energy systems, the performance and features of instantaneous gas, large storage gas and indirect gas water heaters, and combined hydronic equipment, if installed, must be included in the *Special Features and Modeling Assumptions listing* if energy credit is taken for such systems. When combined hydronic systems, solar water heating, or wood stove boilers are used, ACM's must augment the Water Heating Systems listing with the inclusion of two additional listings, Water Heating Systems Misc and Water Heater/Boiler Details. The use of these optional capability features must be reported in the *Special Features and Modeling Assumptions* listing with cross references to the Water Heating Systems Misc and Water Heater/Boiler Details listings, and the content of these listings verified as *Special Features*.

WATER HEATING SYSTEMS

System Name	Distribution Type	Water Heater Name	Water Heater Type	Number of Heaters (#)	Energy Factor	Tank Volume (gal)
Upper Floors	Recirc/Timer	State100	StorGas	3	.52	100
Lower Floors	Recirc/Timer	State50	StorGas	4	.62	50
Kitchens	POU	Loch006	InstElec	18	.98	na.

- *System Name (text):* Unique descriptive name for the water heating system. The name must be linked to entries in the Water Heating Systems Misc and Water Heater System Assignments listings.
- *Distribution Type (recommended descriptor):* The type of distribution system used to transport hot water from the water heater to the point of use. Qualifying requirements for these distribution systems are included in Section 6.6 of the *Residential Manual*.

  Permissible types: Listed in Table R2-5

Table R2-5 - Water Heating Distribution System Descriptors

Recommended Descriptor	Distribution System Reference
Std	Standard (non-recirculating) potable water heating system with tank storage remote from points of consumptive use
POU	Point-of-use potable water heating system, within 8' of fixtures
HWR (optional)	Standard system with hot water recovery capability
Std/PIns	Standard system with pipe insulation entire length of piping run
ParallelPiping	Individual pipes from the water heater to each point of use
Recirc	Recirculation system, continuous operation w/o control
Recirc/Timer	Recirculation system, timer controlled
Recirc/Dmd	Recirculation system, demand controlled
Recirc/Temp	Recirculation system, temperature controlled
Recirc/Timer/Temp	Recirculation system, timer + temperature controlled
R/D&HWR	Combination *Recirc/Dmd* + *HWR*
R/D&PIns	Combination *Recirc/Dmd* + *PIns*

- *Water Heater Name (text):* User-defined descriptive name that is specified in the Water Heater Systems and Water Heater/Boiler Details listings.
- *Water Heater Type (recommended descriptor)*: The type or category of water heater used. Permissible types: Listed in Table R2-6

Table R2-6 - Water Heater Type Descriptors

Recommended Descriptor	Water Heater Reference
StoGas	gas[2]- or oil-fired storage tank 2 gal, input 75,000 Btu/hr
LgStoGas	gas- or oil-fired storage tank, input > 75,000 Btu/hr
StoElec	electric-resistance-heated storage tank 2 gal
InstGas	instantaneous gas-fired, storage < 2 gal
InstElec	instantaneous electric-resistance-heated, storage < 2 gal
StoHP	electric heat pump with storage tank
IndGas	storage tank indirectly heated by gas- or oil-fired source
Boiler	boiler dedicated solely to hydronic space heating

- *Num of Heaters (#)*: The quantity of water heaters of this type in the system.
- *Energy Factor (fraction)*: Applicable to all water heater types subject to National Appliance Energy Conservation Act (NAECA) regulations. Does not apply to *LgStoGas* types; for these types enter "na". If the energy factor is not published, then the water heater is not covered by NAECA and the Water Heater/Boiler Details listing must be completed.
- *Tank volume (gal)*: The listed storage volume of the water heater.

Note: When water heaters with an Energy Factor (EF) of less than 0.58 are installed, the *Special Features and Modeling Assumptions* must list the EF of the water heater and the R-value of externally-applied insulation

[2] Gas may be natural gas or propane.

wrap in hr-ft2̃-F/Btu as well as the mandatory R-value requirement for external insulation for these water heaters.

Water Heating Systems Misc. This listing details credits associated with the use of solar water heating, wood stove boilers and provides information about combined hydronic pump energy for electric combined hydronic systems. A credit may be taken for either a solar water heating system or a wood stove boiler, but not both.

WATER HEATING SYSTEMS MISC *(Example Listing)*

System Name	Solar Savings Fraction	Solar System Type	Wood Stove Boiler?	Wood Stove Boiler Pump?	Combined Hydronic Pump Power (Watts)
Hydronic	0.00	*None*	*Yes*	*Yes*	60.00
DHW	0.64	*Passive*	*No*	*No*	

- *System Name (text):* Descriptive name corresponding to a system name defined in the Water Heating Systems listing.
- *Solar Savings Fraction (fraction):* Fraction of the annual heating load for the system met by solar energy, if the water heating system uses a solar system to provide auxiliary heating. The Solar Savings Fraction may be determined using *f-Chart* or other methods approved by the Commission.
- *Solar System Type (prescribed descriptor)*: Defines the general type of solar system.
- Permissible types: *Active* (pump/blower assisted solar collection/circulation), *Passive* (natural collection/circulation), and *None*
- *Wood-Stove Boiler (prescribed descriptor)*: Indicates whether a wood-stove boiler is used.
- Permissible entries: *Yes* and *No.*
- *Wood-Stove Boiler Pump (prescribed descriptor)*: Indicates whether a wood-stove boiler pump is used to circulate water between the wood stove and the storage tank.
- Permissible entries: *Yes* and *No.*
- *Combined Hydronic Pump (Watts):* Required only for electric combined hydronic *(Elec/*, *StoElec/ and InstElec/CombHydro*) systems. Not required for storage gas/oil or heat pump combined hydronic systems (*StoGas/, LgStoGas/, and StoHP/CombHydro*).

Water Heater/Boiler Details. This listing provides information about the energy characteristics of the water heaters or boilers used in combined hydronic (*CombHydro*) systems and for non-NAECA water heaters; it will not be applicable to the remainder. In such cases, "na" may be reported.

WATER HEATER/BOILER DETAILS *(Example Listing)*

Water Heater Name	Recovery Efficiency (fraction)	AFUE (fraction)	Rated Input (kBtu/hr)	Standby Loss (fraction)	Tank R-value (hr-ft2-/F/Btu)	Pilot Energy (Btu/hr)
CombHydState100	0.78	na	60.00	na	na	na
BigRmWH	0.79	na	75.00	0.04	15.30	na

- *Water Heater Name (text):* Name of water heater specified in the Water Heating Systems listing. In the case of a hydronic system heater, the name should be descriptive of this function to distinguish it from any domestic water system heaters.
- *Recovery Efficiency (fraction):* Recovery efficiency is the performance measure for instantaneous gas water heaters (*InstGas*), large storage gas/oil water heaters (*LgStoGas*) and indirect gas/oil water heaters (*IndGas*). It is also required for storage gas/oil water heaters (*StoGas*) used in combined hydronic systems (*CombHydro*). The value is taken from the Commission's appliance databases[3] or from the manufacturer's literature. If the value is omitted for NAECA regulated water heaters, then the default value will be assumed. When boilers are used to fire an indirect gas/oil water heater (*IndGas*), the value of the AFUE (see below) is used for the recovery efficiency.
- *AFUE (fraction):* Annual Fuel Utilization Efficiency, the heating efficiency of the water heater based upon approved test methodologies. Values of AFUE are listed in the Commission's directories cited above.
- *Rated Input (kBtu/hr):* The energy input rating from the above directories or from the manufacturer's literature. Entries are required for large storage gas/oil water heaters *(LgStoGas)*, indirect gas/oil water heaters (*IndGas*), and when storage gas water heaters (*StoGas/LgStoGas*) or heat pump water heaters (*StoHP*) are used in combined hydronic space heating systems (*CombHydro*).
- *Standby Loss (fraction):* The fractional storage tank energy loss per hour during non-recovery periods (standby) taken from the Commission's directories cited above. Applicable only to large storage gas water heaters (*LgStoGas*).
- *Tank R-value (hr-ft2̃-F/Btu):* The total thermal resistance of the internally-insulated tank and any external insulation wrap. Applicable to large storage gas/oil (*LgStoGas*) and indirect gas/oil (*IndGas*) water heaters only.
- *Pilot light (Btu/hr)*: The pilot light energy consumption rating from one of the Commission's directories, cited above. Applicable only to instantaneous gas (*InstGas*) and indirect gas/oil (*IndGas*) water heaters.

Special Features and Modeling Assumptions. This listing must **stand out and command the attention** of anyone reviewing this form to emphasize the importance of verifying these Special Features and the aspects of these features that were modeled to achieve compliance or the energy use results reported. This listing in the Certificate of Compliance must include any special features of the building that affect the building's compliance with the standards and which are not described elsewhere on the Certificate of Compliance. For example, water heating features, or auxiliary credits must be listed under "*Special Features and Modeling Assumptions*" as well as being listed under a special listing of their own. The use of certain non-default values must also be

[3] The complete appliance databases can be downloaded from the Energy Commission's Internet FTP site (ftp://energy.ca.gov/pub/efftech/appliance/). This requires database software (spreadsheet programs cannot handle some of the larger files). To use the data, a user must download the database file (or files), download a brand file and a manufacturer file and then decompress these files. Then download a description file that provides details on what is contained in each of the data fields. With these files, and using database software, the data can be sorted and manipulated. Directories approved by the Commission may also be used. Currently the Commission has approved the Gas Appliance Manufacturers Association (GAMA) *Consumers' Directory of Certified Efficiency Ratings for Residential Heating and Water Heating Equipment* directory to be used to verify certification on *some* residential appliances. The GAMA directory (Sections I and II) can be used for gas furnaces, boilers and water heaters.

included in this list. These special default values are indicated in the subsequent text. This listing should also include any variations in building features necessary to achieve compliance in multiple orientations.

SPECIAL FEATURES AND MODELING ASSUMPTIONS: (*Example Listing*)	Plan	Field
This house has Zonal control with multiple zones, interzone surfaces, and interzone ventilation.		
This building uses metal-framed walls that must meet mandatory insulation requirements. In this case R-7 sheathing has been used in addition to the R-13 cavity insulation. For these walls.		
This house has an attached sunspace with interzone surfaces, custom solar heat gain distribution and sunspace thermal mass elements		
This house is modeled with reduced infiltration and/or mechanical ventilation. Consequently the homeowner's manual provided by the builder to the homeowner must include operating instructions for the homeowner on how to use operable windows and/or mechanical ventilation to achieve adequate ventilation.		

HERS Required Verification. Specific features that require diagnostic testing to assure proper installation require field testing and verification by a certified home energy rater (HERS rater) under the supervision of a CEC- approved HERS provider, and must be listed in this section. This listing must **stand out and command the attention** of anyone reviewing this form to emphasize the importance of HERS verification of these features and the aspects of these features that were modeled to achieve compliance or the energy use results reported.

All items in the *HERS Required Verification* listings must also report that the installer and HERS rater must both provide the appropriate CF-6R documentation for proper installation, testing, and test results for the features that require verification by a HERS rater. The installer must document and sign the CF-6R to verify compliance with design and installation specifications. The HERS rater must document and sign the CF-6R to confirm the use of proper testing procedures and protocol, to report test results, and to report field verification of installation consistent with the design specifications needed to achieve these special compliance efficiency credits.

The ACM must ask the user if there are vented combustion appliances inside the conditioned space that draw air for combustion from the conditioned space prior to any entry for reduced infiltration or mechanical ventilation. Cooking appliances, refrigerators and domestic clothes dryers are excluded from this requirement. If appliances other than cooking appliances, refrigerators and domestic clothes dryers are present and use conditioned air for combustion, the ACM must instruct the user that reduced infiltration must not be modeled when these devices are part of the Proposed Design and block data entries and ACM modeling of reduced infiltration and mechanical ventilation. When the user indicates that such devices are present or when the user models reduced infiltration or mechanical ventilation, the ACM must report in the *Special Features and Modeling Assumptions* listings that reduced infiltration and/or mechanical ventilation are prohibited from being modeled when vented combustion appliances, not excluded above, are inside conditioned space.

When a *Proposed Design* is modeled with a reduced target infiltration ($CFM50_H$) that corresponds to an SLA less than 3.0, mechanical ventilation is required and must be reported in the *HERS Required Verification* listings.

HERS REQUIRED VERIFICATIONS : (*Example Listing)*	Plan	Field
This house is using reduced duct leakage to comply and must have diagnostic site testing of duct leakage performed by a certified HERS rater under the supervision of a CEC-approved HERS provider. The results of the diagnostic testing must be reported on a CF-6R form and list the target and measured CFM duct leakage at 25 pascals.		
This house has tight construction with reduced infiltration and a target blower door test range between 586 and 1250 CFM at 50 pascals. The blower door test must be performed using the ASTM *Standard Test Method for Determining Air Leakage Rate by Fan Pressurization*, ASTM E 779-87 (Reapproved 1992).		
WARNING: If this house tests below 586 CFM at 50 pascals, the house must either be provided with a ventilation opening that will increase the tested infiltration to at least 586 CFM at 50 pascals (SLA = 1.5) OR mechanical supply ventilation must be provided that can maintain the house at a pressure of at least -5 pascals relative the outside average air pressure while other continuous ventilation fans are operating. Note also that the Commission considers an SLA≤1.5 to be "unusually tight" per the Uniform Mechanical Code.		
WARNING - Houses modeled with reduced infiltration are prohibited from having vented combustion appliances other than cooking appliances, refrigerators and domestic clothes dryers that use indoor air for combustion inside conditioned space.		

Compliance Statement and Signatures. Signature requirements and other details on the compliance statement are included in Section 1.3 of the *Residential Manual*.

COMPLIANCE STATEMENT
This certificate of compliance lists the building features and performance specifications needed to comply with the Energy Standards in Title 24, Parts 1 and 6, of the California Code of Regulations, and the Administrative regulations to implement them. This certificate has been signed by the individual with overall design responsibility. When this certificate of compliance is submitted for a single building plan to be built in multiple orientations, any shading feature that is varied is indicated in the *Special Features and Modeling Assumptions* section.

Designer or Owner (per Business & Professions Code)		**Documentation Author**	
Name	______________________	Name	______________________
Title/Firm	______________________	Title/Firm	______________________
Address	______________________	Address	______________________
City & Zip Code	______________________	City & Zip Code	______________________
Telephone	______________________	Telephone	______________________
License Number	______________________	Signature/Date	______________________
Signature/Date	______________________		
Enforcement Agency			
Name	______________________		
Title	______________________		
Agency	______________________		
City	______________________		
Telephone	______________________		
Signature/Date	______________________		

2.2 Computer Method Summary (C-2R)

The second standard report, that must be automatically produced, gives more detail about the program inputs. The Computer Method Summary must always accompany the Certificate of Compliance when the computer performance approach is used.

The Computer Method Summary shall include all information provided by the program user.

Information on the Computer Method Summary is provided below to illustrate the use of all the standard tables.

Report Heading. The following heading shall appear on the first page of each Computer Method Summary.

COMPUTER METHOD SUMMARY		Page 1 of 4 C-2R
Project Title	Filename:	Date:
Project Address		<runcode>
Documentation Author		<initiation time>
Telephone		Building Permit #
Compliance Method		Plan Check / Date
Climate Zone		Field Check/ Date

The following heading shall appear on subsequent pages.

COMPUTER METHOD SUMMARY		Page 2 of 4 C-2R
Project Title	Filename:	Date:
	<runcode/initiation time>	

Energy Use Summary. This section compares the energy use of the proposed building to the energy budget of the standard design building. All units in this table are TDV~~source~~ kBtu/ft^2-year. Energy is shown for space heating, space cooling and hot water. The space heating and cooling energy budgets are determined from the standard design using the custom budget method. The water heating budget is calculated from the water heating calculation methods described in this document~~budget equation contained in the standards~~. ACM vendors may add additional columns to this report when appropriate, such as for multi-zone building analyses.

ENERGY USE SUMMARY~~ (kBtu/ft^2-yr)~~

TDV (kBtu/ft^2-yr)	Standard Design Energy Budget	Proposed Design Energy Use
Space Heating	23.45	21.23
Space Cooling	10.34	8.23
Water Heating	15.90	14.67
Total	49.69	44.13

Additional rows may be added to the table when necessary to accommodate energy uses that are to be included in the analysis but cannot be easily assigned to one of the three principal categories. For example, an additional row for miscellaneous electrical energy may be required if electric equipment energy use cannot be assigned separately to heating, cooling or hot water.

General Information. This section contains general information about the project.

GENERAL INFORMATION

Conditioned Floor Area:	1384 ft^2
Building Type:	Single-family detached
Building Front Orientation:	0 deg (North)
Number of Dwelling Units:	1
Number of Stories:	1
Floor Construction Type:	Slab on grade
Number of Conditioned Zones:	2
Total Conditioned Volume:	11072 cf
Conditioned Slab Floor Area:	1384 ft^2
Total Conditioned Floor Area:	1384 ft^2

- *Conditioned Floor Area.* The conditioned floor area of all building zones modeled in the computer run.
- *Building Type.* The type of building. Possible types are single-family detached, single-family attached (which includes duplexes and halfplexes) multi-family (all other attached dwellings including condominiums), addition alone, addition plus existing, or alteration.
- *Building Front Orientation.* The azimuth of the front of the building. This will generally be the side of the building where the front door is located. A typical reported value would be "290° (west)". This would indicate that the front of the building faces north 70° west in surveyors terms. The closest orientation on 45° compass points should be verbally reported in parenthesis, e.g. north, northeast, east, southeast, south, southwest, west or northwest. When compliance is shown for multiple orientations, "all orientations" may be reported. When "all orientations" is reported, the *Special Features and Modeling Assumptions* listing shall describe shading features that vary with orientation.
- *Number of Dwelling Units.* The total number of dwelling units in the building. This number may be a fraction for cases of addition alone.
- *Number of Stories*. The number of building stories as defined by the *Uniform Building Code*.
- *Floor Construction Type.* The floor construction type determines the basis of the custom budget or the standard design building; choices are slab or nonslab. Rules for determining the type of floor construction are discussed in Chapter 3 of this Manual.
- *Number of Conditioned Zones.* The number of conditioned zones modeled in the computer run.
- *Total Conditioned Volume.* The total volume of conditioned space within the building.
- *Conditioned Slab Floor Area.* The total area of slab floor (on grade or raised) with conditioned space above and the ground or unconditioned space below. This is used to determine the standard design mass requirement for buildings and the default values of the thermal mass requirements for the proposed design.
- Total Conditioned *Floor Area.* The total floor area of conditioned space in the building to be permitted. This area must be no less than the *Conditioned Slab Floor Area* specified above. The conditioned nonslab floor area is the difference between the *Total Conditioned Floor Area* and the *Conditioned Slab Floor Area* and is used to determine the thermal mass for the Standard Design, the default value of thermal mass for the Standard Design, and the threshold thermal mass requirement for thermal mass credit in the Proposed Design. The conditioned nonslab floor area includes any nonslab floors, raised or not, and raised slab floors with conditioned space above and below the floor.

Building Zone Information. For most compliance documentation, only one row will be reported in this table. Additional rows are reported when a proposed building is modeled as two zones (zonal control), or when attached, unconditioned spaces are modeled, such as crawl spaces or sunspaces.

BUILDING ZONE INFORMATION

Zone Name	Floor Area (ft^2)	Volume (ft^3)	# of Units	Zone Type	Tstat Type	Vent Height (ft)	Vent Area (ft^2)
House	1384	11072	1	Conditioned	Setback	2.0	32

- *Zone Name.* Each zone is given a name that is used to categorize information in the following tables.
- *Floor Area (ft^2).* The floor area of the zone measured to outside wall. The sum of the floor area of all conditioned zones must equal the conditioned floor area reported under "General Information".
- *Volume (ft^3).* The volume of the zone. The sum of the volume of all conditioned zones must equal the total volume reported under "General Information".
- *# of Units.* The number of dwelling units in the zone. This number may be a fraction for cases of addition alone or a building in which there are more zones than dwellings.
- *Zone Type.* This description controls some modeling restrictions, such as infiltration, internal and solar gains, etc. Possible conditioned zone entries are Conditioned, Living and Sleeping. Possible unconditioned zone entries include Unconditioned, CVCrawl and Sunspace.
- *Thermostat Type*. Possible conditioned zone entries are Setback, NoSetback, LivingStat, SleepingStat. Additional thermostat types may be allowed for optional modeling capabilities.
- *Vent Height (ft)*. The height difference between the "inlet" ventilation area and the "outlet" ventilation area. The default ventilation height is determined by the number of stories: one story - 2 feet, two or more stories - 8 feet. Different vent heights may be modeled but a non-default vent height is considered a special feature or special modeling assumption that must be reported in the *Special Features and Modeling Assumptions* listing for special verification. The ventilation height for other windows is the average height difference between the centers of the lower operable window openings and the centers of the upper operable window openings.
- *Vent Area (ft^2)*. This entry is either the default vent area which is assumed by the ACM based on entries in the Fenestration Surfaces table or some other value entered by the user. A Vent Area value greater than 10% of the total rough-out opening area (all windows treated as opening type: “slider”) of all fenestration must be reported in the *Special Features and Modeling Assumptions* listing for special verification.

Opaque Surfaces. A row shall be reported in this table for each unique opaque surface in the proposed building. Opaque surfaces include walls, roofs, floors and doors.

For buildings that are modeled as multiple thermal zones, the opaque surfaces shall be grouped for each zone and indicated with a header "Zone = <ZoneName>". The zone name used in the header should be the same as the name used in the table titled "Building Zone Information"

OPAQUE SURFACES

Surface Type	Area (ft^2)	U-Value	Cavity Insul R-value	Sheath. Insul. R-value	Total R-value	True Azimuth	Tilt	Solar Gains	Form 3 Reference	Location/ Comments
Zone=Living										
Wall	105.4	0.088	R-13	na	11.30	0	90	Yes	Wall-1	Typical
Wall	145.4	0.068	R-11	R-4	14.69	180	90	Yes	Wall-1	Typical
Base WallA	100	0.124	na	R-6	8.08	0	90	No	BWall-1	0-2 ft below grade
Base Wall B	160	0.124	na	R-6	8.08	0	90	No	BWall-2	2-6 ft. below grade
Wall	176.8	0.088	R-13	na	11.30	270	90	Yes	Wall-1	Typical
Roof	692	0.031	R-30	na	32.48	0	0	Yes	Roof-1	Typical
Door	40	0.330	na	na	3.03	0	90	Yes	Door-1	Typical
Zone=Sleep										
Wall	145.4	0.088	R-13	na	11.30	0	90	Yes	Wall-1	Typical
Wall	176.8	0.068	R-11	R-4	14.69	90	90	Yes	Wall-1	Typical
Wall	145.4	0.088	R-13	na	11.30	180	90	Yes	Wall-1	Typical
Roof	692	0.031	R-30	na	32.48	0	0	Yes	Roof-1	Typical
Zone=SunSpc										
Wall	72	0.088	R-13	na	11.30	90	90	Yes	Wall-1	Sunspace Wall
Wall	90	0.088	R-13	na	11.30	180	90	Yes	Wall-1	Sunspace Wall
Wall	72	0.088	R-13	na	11.30	270	90	Yes	Wall-1	Sunspace Wall
Roof	135	0.031	R-30	na	32.48	0	0	Yes	Roof-1	Sunspace Roof

- *Surface Type.* Valid types are Wall, BaseWallA (0-1.99 ft below grade), BaseWallB (2.0-5.99 ft below grade), BaseWallC (more than 6 ft below grade), Roof/Ceiling, and Floor. If floor is over a crawl space (FlrCrawl), then the U-values used in the custom budget run are based on having a crawl space. Otherwise, they are not. Floor types and areas are also used to determine the default thermal mass for the Proposed Design and the thermal mass for the Standard Design.
- *Area (ft^2).* The area of the surface.
- *Assembly U-value.* The overall U-value of the surface assembly. (U-values are calculated using standard engineering principles as documented in the *Residential Manual*[4], Appendix G and Appendix H.
- *Cavity Insul R-val.* The rated R-value of the installed insulation in the cavity between framing members. This does not include framing effects or the R-value of drywall, air films, etc. When insulating sheathing is installed over a framed wall, the "Cavity Insul R-val" should report the insulation in the cavity only.
- *Sheath Insul R-val.* The sum total rated R-value of all installed layers of insulating sheathing (R-2 or greater). Multiple sheathing layers must report the total of the sum of the R-values for all insulating sheathing layers. Gypsum board and exterior siding layers are not included unless they have an R-value greater than 2.0. Cavity insulation is not reported. The R-values of air films are not included
- *Total R-value.* The total R-value of the opaque surface assembly. This includes framing effects and the R-value of drywall, air films, etc. For below grade walls this value does not include the outside air film nor the

[4] *2001 Residential Manual*, California Energy Commission Publication P400-00-029.

R-value of the adjacent soil or gravel. For raised floors over a crawlspace, this value does not include the R-value for the crawlspace.

- *True Azimuth.* The actual azimuth of the surface after adjustments for building rotation. There are various ways of describing the orientation or azimuth of surfaces. For ACMs approved by the CEC, a standard convention must be used. The azimuth is zero degrees for surfaces that face exactly north. From this reference the azimuth is measured in a clockwise direction. East is 90 degrees, south 180 degrees and west 270 degrees.
- *Tilt.* The tilt of the surface. Vertical walls are 90°; flat roofs are 0°; floors are 180°.
- *Solar Gains.* A yes/no response is given to indicate if a surface receives solar gains. Surfaces that do not receive solar gains may include floors over crawl spaces and walls adjacent to garages. Only a yes/no response is required since the surface absorptance is a fixed input.
- *Form 3 Reference.* A reference to attached Form 3's that may accompany the compliance documentation. This name may also be referenced from the thermal mass table to indicate an exterior mass wall.
- *Location/Comments.* User provided text describing where the surface is located or other relevant information.

Perimeter Losses. This table provides details about components of the building envelope that are modeled as perimeter losses. Typical perimeter losses are slab edge losses, retaining wall losses, and losses from the base of controlled ventilation crawl spaces. A row is provided in the table for each unique perimeter element. Note that a single F2 factor is reported for slab edge losses for slab floor interiors that are carpeted or exposed based on a fixed assumption of 20% of the edge adjacent to exposed slab. This assumption must be used and separate F2 values for different interior covering conditions may not be reported or modeled by an approved ACM.

For buildings that are modeled as multiple thermal zones, the items shall be grouped for each zone and indicated with a header "Zone = <ZoneName>". The zone name used in the header should be the same as the name used in the table titled "Building Zone Information"

PERIMETER LOSSES

Perimeter Type	Length (ft)	F2 Factor	Insul R-val	Insul Depth (in)	Location/Comments
Zone=Living					
SlabEdge	76	0.75	R-3	8	Exposed edge
Zone=Sleep					
SlabEdge	76	0.75	R-3	8	Exposed edge
Zone=SunSpc					
SlabEdge	65	0.90	R-0	na	Exposed edge

- *Perimeter Type.* The perimeter type. Possible types are slab edge, crawl space perimeter, etc. Names may be abbreviated.
- *Length (ft).* The perimeter length in feet.
- *F2 Factor.* The perimeter heat loss factor (see Section 4.22).
- *Insul R-Val.* The R-value of the installed insulation. "R-0" or "None" should be reported when no insulation is installed.
- *Insul Depth (in).* The depth that the insulation extends below the top surface of the slab in inches.
- *Location/Comments.* User provided information on the location of the perimeter element or other relevant information.

Fenestration Surfaces. This listing must include information about each fenestration surface in the proposed building. Fenestration surfaces include windows, skylights and glazing in doors or other transparent or translucent surfaces. One row is included in the listing for each unique fenestration condition. ACMs must restrict users to select from a limited list of exterior shading devices and their associated solar heat gain coefficients (SHGCs), namely, those devices and SHGCs listed in Table R2-1 - Allowed Exterior Shading Devices and Recommended Descriptors for exterior shading devices. ACMs shall not allow users to enter custom shading devices nor account for differences in alternative color, density, or light transmission characteristics. ACMs are required to calculate, but not report, $SHGC_{open}$ and $SHGC_{closed}$ using 2001 Standards calculation procedures and assumptions.

For buildings that are modeled as multiple thermal zones, the fenestration surfaces shall be grouped for each zone and indicated with a header "Zone = <Zone Name>". The zone name used in the header should be the same as the name used in the table titled "Building Zone Information"

FENESTRATION SURFACES

Fenestration #/Type/Orien	Area (ft^2)	U-factor	Fenes.SHGC	True Az	Tilt	Exterior Shade Type /SHGC
Zone=Living						
1 Wdw Front(N)	70.4	0.65	0.88	0	90	
2 Wdw Left(E)	70.4	0.65	0.88	90	90	WveScrn/ 0.39
Zone=Sleeping						
3 Wdw Back(S)	70.4	0.65	0.88	180	90	
4 Wdw Right(W)	70.4	0.65	0.88	270	90	LvrScrn/ 0.36

- *Fenestration #/Type/Orien.* The # is a unique number for each different fenestration surface entry. The type is Wdw (window) Dr (door) or Sky (skylight). The *Orien* (orientation) is the side of the building (front, left, right or back) followed by the nearest 45° compass point in parenthesis (N, NE, etc.). When compliance is for all orientations, only the side of the building may be reported (front, right, etc.)
- *Area (ft^2).* The area of the surface in square feet. This should generally be the rough frame opening.
- *U-value*. The rated U-value of the fenestration product, in Btu/h-ft^2-°F.
- *True Azimuth.* The true (or actual) azimuth of the glazed surface after adjustment for building rotation. The convention for describing the azimuth is standardized as discussed above under opaque surfaces.
- *Tilt.* The tilt of the glazed surface. Most windows will have a 90° tilt. Skylights typically have a tilt equal to the corresponding roof surface.
- *Fenestration SHGC:* The solar heat gain coefficient of the fenestration.
- *Exterior Shade Type/SHGC*. The type of exterior shading device and its solar heat gain coefficient from Table R2-1 - Allowed Exterior Shading Devices and Recommended Descriptors. "*Standard/0.76*" or " " must appear when no special exterior shading device is included in the building plans. *Standard (partial bugscreen)* shading shall automatically be given for all window area without other forms of exterior shading devices. This shading assumes that a portion of the window area is covered by bugscreens. Other valid exterior shades include louvered screens (*LvrScrn*), woven sunscreen (*WvnScrn*), and Low Sun Angle Sunscreen (*LSASnScrn*). When used for compliance purposes, ACMs shall not allow or accept input for user-defined exterior shades.

Solar Gain Targeting*.* This table is only used for special cases, such as sunspaces (an optional modeling capability, and hence a Special Feature). Solar gains that enter conditioned spaces must be targeted to the air, but when glazing surfaces enclose unconditioned spaces, such as sunspaces, the user is allowed to target all but 25% of the solar gains from these surfaces to mass elements located within the unconditioned space. More than one row of targeting data may be included for each glazed surface. Unassigned solar gain is targeted to the air in the unconditioned space. At least 25% of the solar gain from any sunspace fenestration surface must be targeted to high surface area lightweight mass or the air. At most 60% of the solar gain may be targeted to the slab floor of a sunspace, especially in the summer. An ACM must automatically enforce these limits and inform the user of any attempt to exceed these limits.

Note that the use of any optional capability such as sunspace modeling must be reported in the *Special Features and Modeling Assumptions* listings. In addition, solar gain targeting must be separately reported in the *Special Features and Modeling Assumptions* listings so that the local enforcement agency can verify that these inputs are reasonable.

SOLAR GAIN TARGETING

Fenestration #/Type/Orien	Mass Name	Winter Fraction	Summer Fraction
1 Wdw Front(N)	SSSlb	0.30	0.30

- *Fenestration #/Type/Orien.* The fenestration surface which transmits solar gain to an interior unconditioned space thermal mass. This corresponds to an item in the fenestration surfaces table.
- *Mass Name.* The name of the mass element to which solar gains are directed. The mass name corresponds to an item in the thermal mass table.
- *Winter Fraction.* The fraction of solar gains targeted from the glazing surface to the absorbing thermal mass when the building is in a heating mode.
- *Summer Fraction.* The fraction of solar gains targeted from the glazing surface to the absorbing thermal mass when the building is in a cooling mode.

Overhangs. Overhangs are a minimum ACM capability and are described in this table.

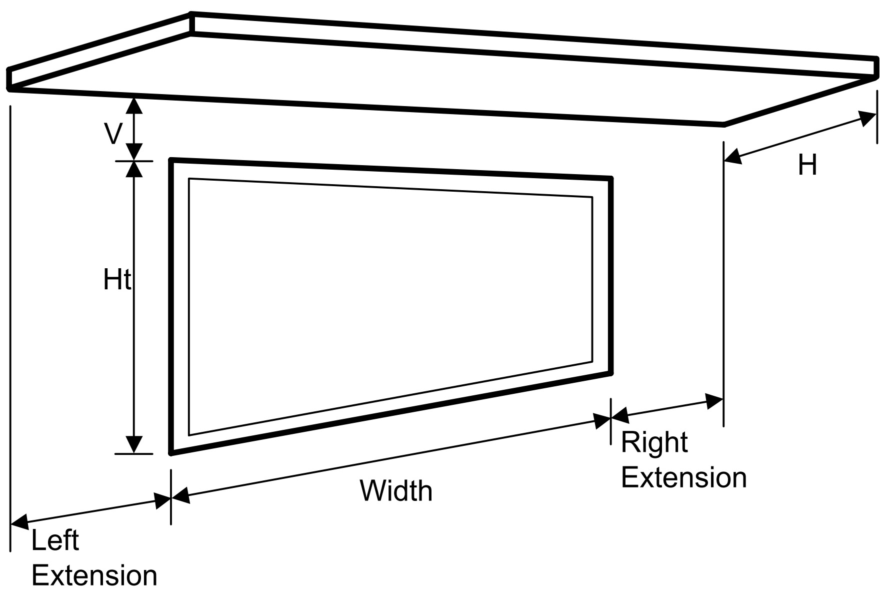


Figure 2-1 - Overhang Dimensions

OVERHANGS

Fenestration			Overhang			
#/Type/Orien	Wdth	Ht	Lngth "H"	Ht "V"	Left Extension	Right Extension
3 Wdw Back(S)	4.0	5.0	2.6	1.5	6.0	6.0

- *Fenestration #/Type/Orien.* This corresponds to an item in the fenestration surfaces list.
- *Fenestration Wdth.* The width of the rough-out frame opening for the fenestration (in feet) measured from the edge of the opening on one side to the edge of the opening on the other side.
- *Fenestration Ht.* The height of the rough-out frame opening for the fenestration (in feet) measured from the bottom of the opening or frame to the top of the opening or frame.
- *Overhang Lngth "H".* The horizontal distance in feet from the surface of the glazing to the outside edge of the overhang.
- *Overhang Ht "V".* The vertical distance (in feet) from the top of the glazing frame to the bottom edge of the overhang at the distance "H" from the glazing surface. See Figure 2-1.
- *Overhang Left Extension.* The distance in feet from the left edge of the glazing frame to the left edge of the overhang. "Left" and "right" are established from an exterior view of the window.
- *Overhang Right Extension.* The distance in feet from the right edge of the glazing frame to the right edge of the overhang.

Side Fins. Side fins are an optional capability. If an ACM does not provide this option, then this table is not used.

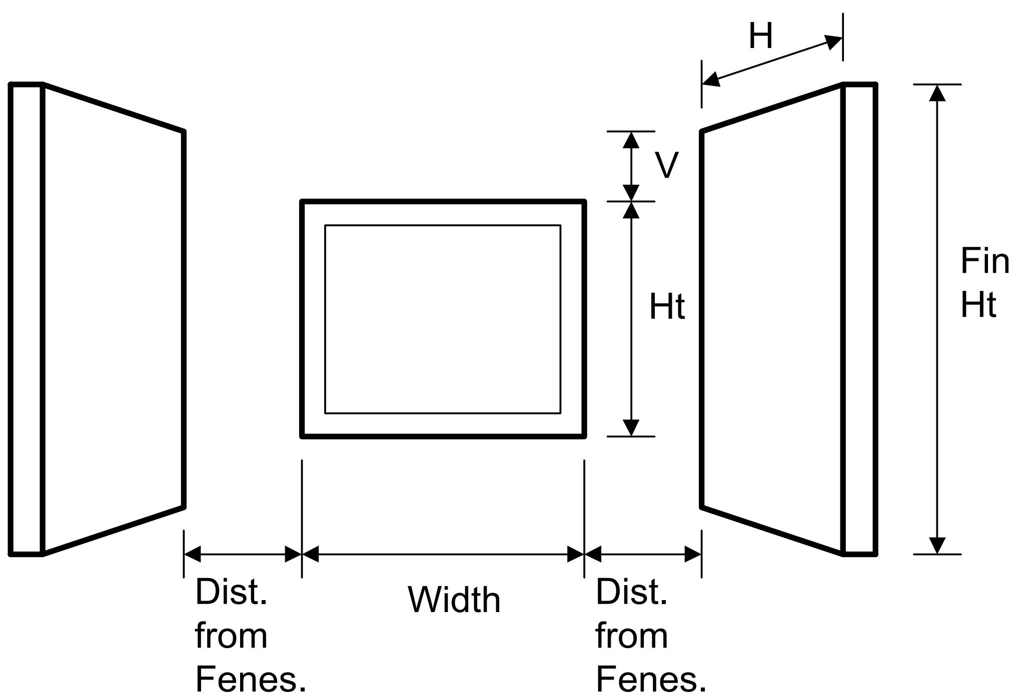


Figure 2-2 - Side Fin Dimensions

SIDE FINS

Fenestration			Left Fin				Right Fin			
#/Type/Orien	Wdth	Ht	Dist from fenes	Lngth "H"	Ht "V"	Fin Ht	Dist from fenes	Lngth "H"	Ht "V"	Fin Ht
3 Wdw Back(S)	4.0	5.0	6.0	2.0	6.0	8.0	6.0	2.0	6.0	8.0

- *Fenestration #/Type/Orien.* This must correspond to an item in the fenestration surfaces list.
- *Fenestration Wdth.* The width of the rough-out opening for the fenestration (in feet) measured from the edge of the opening or frame on one side to the edge of the opening or frame on the other side.
- *Fenestration Ht.* The height of the rough-out opening for the fenestration (in feet) measured from the bottom of the opening or frame to the top of the opening or frame.
- *Left Fin Dist from fenes*. The distance in feet from the nearest glazing frame edge to the fin. "Left" and "right" are established from an exterior view of the window.
- *Left Fin Lngth "H".* The horizontal distance in feet from the surface of the glazing to the outside edge of the fin..
- *Left Fin Ht "V"*. The vertical distance (in feet) from the top of the glazing frame to the top edge of the fin.
- *Left Fin, Fin Ht.* The height of the fin, in feet.
- *Right Fin.* Similar to Left Fin items.

Inter-Zone Surfaces. This listing is used only for proposed designs modeled as multiple thermal zones which is considered an exceptional condition and must also be listed in the *Special Features and Modeling Assumptions* listings for the CF-1R and the C-2R. The *Special Features and Modeling Assumptions* listing must direct plan and field checkers to the listings for *Interzone Surfaces* and *Interzone Ventilation*. The *Interzone Surfaces* listing describes the characteristics of the surfaces that separate the zones.

For buildings that are modeled with more than two thermal zones, the inter-zone surfaces shall be grouped so that it is clear which zones are separated by the surfaces. The groupings shall be labeled "Between ZoneName1 and ZoneName2" or some similar convention.

INTER-ZONE SURFACES

Surface Type	Area (ft^2)	U-value	Cavity Insul R-val	Sheath Insul R-valu	Form 3 Reference	Location/Comments
Between Living and Sunspc						
Wall	100	0.09	R-11	na	Wall-2	Insulated partition
Glass	30	1.10	SglGls	na		Sliding glass door
Between Sleeping and Sunspc						
Wall	220	0.09	R-11	R-4	Wall-2	Insulated partition
Glass	10	1.10	SglGls	na		Window
Between Living and Sleeping						
Wall	206	0.293	R-0	na	Wall-3	Gypsum partitions
Door	40	0.33	R-0	na		Hollow core doors

- *Surface Type.* The type of surface separating the zones. Possible types are window, wall, etc.
- *Area (ft^2).* The area of the surface in square feet that separates the zones.
- *U-val.* The U-value of the surface.

- *Cavity Insul R-val.* The R-value of insulation installed in cavity of the framed construction assembly. This does not account for framing effects, drywall, air films, etc.
- *Sheath Insul R-val.* The total R-value of all insulation layers (layers R-2 or greater) not penetrated by framing. Excludes low R-value layers such as sheetrock, building paper, and air films.
- *Form 3 Reference*. A reference to attached Form 3's that may accompany the compliance documentation.
- *Location/Comments.* User provided information on the location of the inter-zone surface or other relevant information.

Inter-Zone Ventilation. This listing is used for proposed designs that are modeled as multiple building zones. The modeling of multiple building zones is considered an exceptional condition that must be reported in the *Special Features* and *Modeling Assumptions* listings, which must also refer to the information in this listing when this listing is generated by the ACM to echo user inputs for Inter-Zone Ventilation. If inter-zone ventilation is modeled, it must be reported in this listing. It describes natural and/or mechanical ventilation systems that separate the zones.

For buildings that are modeled with more than two thermal zones, the inter-zone ventilation items shall be grouped so that it is clear which zones are linked by the items. The groupings shall be labeled "Between ZoneName1 and ZoneName2" or some similar convention.

INTER-ZONE VENTILATION

Vent Type	Inlet Area	Outlet Area	Height Diff.	Fan Watts	Fan Flow (cfm)	Location/ Comments
Between Living and Sunspc						
Natural	20	20	3	na	na	

- *Vent Type.* Possible types are natural and fan.
- *Inlet Area.* The area of the air inlet in square feet. This is used only when vent type is "natural".
- *Outlet Area.* The area of the air outlet in square feet. This is used only when vent type is "natural".
- *Height Diff.* The elevation difference between the inlet and the outlet in feet. This is used only when vent type is "natural". Default is two feet.
- *Fan Watts.* The fan power rating in watts. This is used only for sunspaces and only then when vent type is "fan". Fan energy may be reported as a separate line item or added to the TDV~~source~~ energy for heating.
- *Fan Flow (cfm).* The cubic feet per minute of air flow provided when the fan is operating. This is used only for sunspaces and then only when vent type is "fan".
- *Location/Comments*. User provided text describing where the item is located or other relevant information.

Thermal Mass for High Mass Design. This listing can only appear if and when the Proposed Design's thermal mass exceeds the required mass threshold. Exceeding this mass threshold and modeling this mass in the Proposed Design is also considered to be an exceptional condition and must be reported in the *Special Features and Modeling Assumptions* listings on the CF-1R and the C-2R. This listing shall provide detail about the thermal mass elements in the building. One row is provided in the table for each mass element.

Thermal mass elements may be located within a single zone, they may separate zones or they may be located on an exterior wall. Mass elements in each of these categories shall be grouped and labeled accordingly.

THERMAL MASS FOR HIGH MASS DESIGN

Mass Name	Area (ft^2)	Thickness (inches)	Volumetric Heat Capacity (Btu/ft^3-°F)	Conductivity (Btu-in)/(hr-ft^2-°F)	Form 3 Reference	Inside Surface R-value (hr-ft^2-°F)/Btu	Location/Comments
Zone=Living							
ExpSlb-L	273	3.5	28	.98	na	0	Exposed in living
CarSlb-L	419	3.5	28	.98	na	2	Carpeted in living
Zone=Sleep							
ExpSlb-S	273	3.5	28	.98	na	0	Exposed in sleeping
CarSlb-S	419	3.5	28	.98	na	2	Carpeted in sleeping
Zone=SunSpc							
SSSlb	450	3.5	28	.98	na	0	Sunspace slab
Between Sunspc and Living							
SSWall	100	8.0	28	.98	na	0	Masonry wall

- *Mass Name.* The name of the mass element. This name may be referenced from the optional solar gains targeting section of the fenestration surfaces table.
- *Area (ft^2).* The area of the mass in square feet.
- *Thickness.* The mass thickness in inches.
- *Heat Capacity.* The volumetric heat capacity of the mass material in Btu/F-cf.
- *Conductivity.* The conductivity of the mass material in Btu-in/hr-ft^2-°F.
- *Form 3 Reference.* A reference to a wall Form 3. This may be used when a mass element is part of an exterior wall to describe an exterior mass wall or the link between a mass material and an opaque wall surface. The mass area should be the same as the sum of the wall surface areas that reference it.
- *Inside Surface R-value.* The thermal resistance of any material (such as carpet or tapestry) that may exist on the inside surface of the thermal mass excluding air films. For instance, if a mass element is carpeted, a surface R-value of 2 is the fixed input. For mass elements that separate thermal zones, the surface R-value may be reported separately for each side of the mass.
- *Location/Comments.* User provided information on the location of the mass element or other relevant information.

HVAC Systems. Information is provided on the type of heating and cooling systems proposed for each zone of the building. Data in the table is organized to accommodate any type of heating or cooling system so some of the information is not applicable for all system types. When the information is not applicable, "na" is reported. Data in this table should be organized first by heating and cooling system. Note that the thermostat type is reported under "Building Zone Information" described above.

For buildings that are modeled as multiple thermal zones, the items shall be grouped for each zone and indicated with a header "Zone = <ZoneName>". The zone name used in the header should be the same as the name used in the table titled "Building Zone Information"

HVAC SYSTEMS

Equipment Type	Minimum Equipment Efficiency (or Water Heating System Name)[5]	Refrigerant Charge ~~and Airflow~~	Distribution Type and Location	Duct R-value
Zone=Living				
Furnace	0.78 AFUE	N/A	DuctsCrawl	~~4.2~~8
AirCond-Split	10.0 SEER	Yes	DuctsCrawl	~~4.2~~8
Maximum Allowable Cooling Capacity 23293 Btu/hr Adequate Airflow @400 cfm/ton: 776 cfm				
Zone=Sleep				
CombHydro	Upper Floors	N/A	Baseboard	na.
AirCond-Split	10.0 SEER	No	DuctsAttic	~~4.2~~8
Maximum Allowable Cooling Capacity 15730 Btu/hr Adequate Airflow @400 cfm/ton: 524 cfm				

- *Equipment Type.* The type of heating or cooling equipment. This is specified separate from the distribution type. Required heating equipment and cooling equipment entries are listed in Table R2-2 - HVAC Heating Equipment Descriptors andTable R2-3 - HVAC Cooling Equipment Descriptors. When the proposed house is not air conditioned, the entry should be NoCooling. If more than one type of equipment is specified, they may be listed on subsequent rows.
- *Minimum Equipment Efficiency.* The minimum equipment efficiency needed for compliance. The applicable efficiency units should also be reported, for instance AFUE for furnaces and boilers, HSPF for electric heating equipment, and SEER for heat pumps (cooling) and central air conditioners. In the case of combined hydronic heating, the name of the water heating system should be identified. If equipment type is Electric (other than heat pump), an HSPF of 3.413 should be entered, except for radiant systems which use a maximum HSPF of 3.55.
- *Refrigerant Charge ~~and Airflow~~.* The choices are 'yes' or 'no' where 'yes' means that either refrigerant charge ~~and airflow are~~ is verified or a TXV is installed and verified. See Section 2.1 for system types for which this credit can be claimed.• *Distribution Type and Location.* The choices for distribution type and location are shown in Table R2-5 with a brief discussion of each. Any duct location other than all ducts in the attic (*DuctsAttic)* must also be reported in the *Special Features and Modeling Assumptions* listings AND the *HERS Required Verification* listings on the CF-1R and C-2R forms printed by the ACM.

The default distribution type and location is a ducted, central system with 100% of the ducts in the attic. If a duct design is specified with duct locations on the plans but without specific duct surface areas (sizes and lengths) specified, the *Special Features and Modeling Assumptions* listing shall specify the default duct locations that are specified in Section 3.8.4. To use DuctsCrawl or DuctsBsmt, all supply registers must be in the floor and the *Special Features and Modeling Assumptions* listings must indicate that all supply registers are in the floor.

- *Duct R-value.* The installed R-value for duct insulation. The minimum duct insulation is 4.2 which is required by the mandatory measures section.
- *Maximum Allowable Cooling Capacity (Btu/hr).* The maximum allowable cooling capacity.
- *Adequate Airflow Level @ 400 cfm/ton.* The minimum airflow required to meet the adequate airflow criteria calculated at 400 cfm/ton.

[5] "Water Heating System Name" may be omitted from heading, except when combined hydronic systems are used.

Special Systems - Hydronic Distribution Systems and Terminals. This listing must be completed for hydronic systems that have more than 10 feet of piping (plan view) located in unconditioned space. As many rows as necessary may be used to describe the piping system. Note that hydronic heating systems (combined or not) must be reported in the *Special Features and Modeling Assumptions* listings. The entry for the *Special Features and Modeling Assumptions* listings must indicate any additional listings that are reported for this feature so that the local enforcement agency can verify the additional information needed to check this special feature.

SPECIAL SYSTEMS - HYDRONIC DISTRIBUTION SYSTEMS AND TERMINALS

Distribution System Name	Terminal Type	Number (#)	Piping Run Length (ft)	Nominal Pipe Size (in)	Insulation Thickness (in)	Insulation R-value
HydFanCoil	FanCoil	1	15	1.5	1.5	6.0
	Baseboard	1	20	,75	1	4.0
	FanCoil	1	15	.5	1.5	4.0

- *System Name (text):* Description given to the hydronic system.
- *Terminal Type (prescribed descriptor):* The type of terminal equipment used in the system.

  Permissible types: Listed in Table R2-7 - Hydronic Terminal Descriptors.

Table R2-7 - Hydronic Terminal Descriptors

Descriptor	**Hydronic Terminal Reference**
FanCoil	Ducted fan coil used in central systems
Baseboard	Baseboard convector using natural convection
RadiantFlr	Radiant floor

- *Piping Run Length (ft)*. The length (plan view) of distribution pipe located in unconditioned space, in feet, between the primary heating/cooling source and the point of distribution.
- Nominal *Pipe Size.* The nominal (as opposed to true) pipe diameter in inches.
- *Insulation Thickness (in).* The thickness of the insulation in inches. Enter "none" if the pipe is uninsulated.
- *Insulation R-value (hr-ft^2-°F/Btu)*. The installed R-value of the pipe insulation. Minimum pipe insulation for hydronic systems is R-4 for 2" or smaller pipe, and R-6 for pipe diameter larger than 2".

Water Heating Systems. This listing includes information about water heating systems. A water heating system may serve more than one dwelling unit. A system may also have more than one water heater, but may have only one distribution system. Each water heating system in the building is defined in one or more rows in the following table. Data in this table is associated with data in the Water Heating System Credits Table, the Water Heater Equipment Detail Table, and the Water Heating System Assignments Table. When there are multiple water heater types in a system, the last six columns may be repeated as necessary.

WATER HEATING SYSTEMS

System Name	Distribution Type	Water Heater Name	Water Heater Type	Number in System	Energy Factor	Tank Size (gal)
Upper Floors	Recirc/Timer	State100	SG	3	.52	100
		State67	SG	3	.55	67
Lower Floors	Recirc/Timer	State50	SG	4	.62	50
Kitchens	POU	Loch006	IE	18	.98	na.

- *System Name.* This is a user defined name for the water heating system that provides a link between the water heating systems table, the Water Heating Systems Credits Table, and the Water Heater System Assignments Table.
- *Distribution Type.* Several specific distribution systems are recognized. The distribution system will be one of the following choices. Qualifying requirements for these distribution systems are included in Section 6.6 of the *Residential Manual*.

Table R2-8 - Water Heating Distribution Types

Standard	RecrcDmd (recirculation with demand control)
PtOfUse (point of use),	RecrcTmp (recirculation with temperature control)
HtWtrRcv (hot water recovery),	R/D&HWR (recirc/demand & hot water recovery)
PipeInsl (pipe insulation)	R/D&PIns (recirc/demand & pipe insulation)
RecrcNC (recirculation with no controls)	RecrcT&T (recirc with timer and temp controls)
RecrcTim (recirculation with timer control)	PrllPipe (parallel piping)

- *Water Heater Name.* This is a user defined name that provides a link between the Water Heater System Table and the Water Heater Equipment Detail Table.
- *Water Heater Type.* The water heater type will be one of the following choices. The large storage gas water heaters are larger than the 75,000 Btu/h maximum input rated by the National Appliance Energy Conservation Act (NAECA). Indirect gas water heaters are essentially a boiler with a separate storage tank. Additional data required for large storage gas and indirect gas types is entered later in the Water Heater Equipment Detail table. "Gas" is used for propane as well as natural gas. If oil water heaters are used, the "gas" choices may be selected.

Table R2-9 - Water Heater Types

SG (storage gas)	IG (instantaneous gas)
SO(storage oil)	IE (instantaneous electric)
SE (storage electric)	LgG (large storage gas)
HP (heat pump water heater)	IndG (indirect gas)

- *Number in System.* The number of identical water heaters that exist in the system.
- *Energy Factor*. The energy factor is the principal performance factor for water heater types subject to NAECA regulations, including storage gas, storage electric, instantaneous electric and heat pump water heaters. If the energy factor is not published, this means that the water heater is not covered by NAECA and the Water Heater Equipment Detail Table must be completed.
- *Tank Size (gal).* The storage tank capacity in gallons. This input is applicable to all storage type water heaters.
- Note: External Insulation Wrap is no longer allowed as a modeling option for approved ACMs.

Special Water Heating System Credits. This section includes information about water heating auxiliary energy credits, if used. These features are optional capabilities for ACMs and their use for performance compliance requires listing in the *Special Features and Modeling Assumptions* listings of the CF-1R and the C-2R. The *Special Features and Modeling Assumptions* listing must cross-reference the listing below which must be included as part of the C-2R when any of these applicable optional water heating capabilities are modeled by the ACM.

SPECIAL WATER HEATING SYSTEM CREDITS

System Name	Solar Savings Fraction	Pump Energy (Y/N)	Wood Stove Boiler? (Y/N)	Wood Stove Boiler Pump? (Y/N)
Upper Floors	.60	Y	na.	na.

- *System Name.* This is a name corresponding to a system name defined in the water heating systems table.
- *Solar Savings Fraction*. If the water heating system has a solar system to provide auxiliary heating, the solar savings fraction is entered in this column. The solar savings fraction may be determined using f-Chart or other methods approved by the CEC. A system may have solar auxiliary or a wood stove boiler, but not both.
- *Pump Energy (Y/N).* This is a yes/no response to indicate whether or not pump energy should be considered in the ACM calculation. "No" should be entered if the solar system does not have a recirculation pump or if the energy of the pump was already included in the supporting f-Chart analysis. "Yes" is entered only if the system has a pump and it was not considered in the f-Chart analysis. Active solar systems generally have a pump, while thermosyphon and integral collector storage (ICS) systems generally do not.
- *Wood Stove Boiler (Y/N).* This is a yes/no response on whether or not the system has a wood stove boiler. A credit may be taken for either solar systems or for a wood stove boiler, but not both.
- *Wood Stove Boiler Pump (Y/N).* This is a yes/no response to indicate whether the wood stove boiler has a recirculation pump.

Special Water Heater/Boiler Details. This listing describes the equipment that serves the water heating system or systems. It is only necessary to complete this table for combined hydronic systems and for non-NAECA water heaters. The information in the table will not be applicable to every water heater type. The use of these features for performance compliance requires listing in the *Special Features and Modeling Assumptions* listings of the CF-1R and the C-2R. The *Special Features and Modeling Assumptions* listing must cross-reference the listing below which must be included as part of the C-2R when any of these Special Water Heating Equipment characteristics are modeled by the ACM. When the information is not applicable, "na" may be reported.

SPECIAL WATER HEATER /BOILER DETAILS

Water Heater Name	Recovery Efficiency (fraction)	AFUE (fraction)	Rated Input (kBtuh)	Combined Hydronic Pump (watts)	Standby Loss (fraction)	Tank Total R-value (hr-ft^2-°F/Btu)	Pilot Light (Btu/h)
Loch006	na.	0.78	na.		na.	na.	na.
State100 Hydro	na.	0.79	40	40	na.	na.	na.
State50	na.	0.80	na.		na.	na.	na.

- *Water Heater Name.* This is a user defined name that provides a link to the water heater system table. In the case of a hydronic system heater, the name should be descriptive of this function to distinguish it from any domestic water system heaters.

- *Recovery Efficiency (fraction).* Recovery efficiency is the performance measure for instantaneous gas water heaters, large storage gas water heaters and indirect gas water heaters. It is also needed for storage gas water heaters used in combined hydronic systems. The value is taken from the CEC Appliance Database[6]or from manufacturers literature. If the value is omitted for NAECA regulated water heaters, then the default value will be assumed.
- *AFUE (fraction).* The Annual Fuel Utilization Efficiency, the heating efficiency of the water heater based upon approved test methodologies. Values of AFUE are listed in the Commission Appliance Database.
- *Rated Input (kBtu/h).* The energy input, in kBtu/h (thousands of Btus per hour), from the CEC Appliance Database or from manufacturers literature. This is needed for large storage gas and indirect gas water heaters and when storage gas water heaters or heat pump water heaters are used for combined hydronic space heating.
- *Combined Hydronic Pump (watts).* This is needed only for electric combined hydronic systems. It is not needed for storage gas or heat pump combined hydronic systems.
- *Standby Loss (fraction).* The standby loss percent per hour (taken from the CEC Appliance Database or from manufacturers literature) divided by 100. Applicable to large storage gas water heaters only.
- *Tank Total R-value (hr-ft^2-°F/Btus).* The total thermal resistance for both the tank and the insulation. This input is applicable to large storage gas and indirect gas water heaters only.
- *Pilot Light (Btu/h).* The pilot light energy, in Btu/h, from the CEC Appliance Database or from manufacturers literature. This column is only applicable for instantaneous gas water heaters and indirect gas water heaters.

Table R2-10 summarizes the applicability of the inputs for the water heater types recognized by the calculation method.

Table R2-10 - Water Heater Input Summary

Input Item	NAECA Storage Gas	NAECA Storage Electric	NAECA Heat Pump	Instant. Gas	Instant. Electric	Large Storage Gas	Indirect Gas
Energy Factor	Yes	Yes	Yes	Yes	Yes		
Pilot Input, Btu				Yes		Yes	Yes
Efficiency, %[7]						Yes	Yes
Standby Loss, %						Yes	
Tank Volume, gal.	Yes	Yes	Yes			Yes	Yes
Tank Insulation, R						Yes	Yes
Ext. Insulation, R						Yes	Yes
If Combined Hydronic System:							
Rated Input, kBtuh	Yes					Yes	Yes
Rated Input, kWI		Yes	Yes				
Recovery Eff, %	Yes		Yes			Yes	Yes
Pump Input, Watts		Yes				Yes	Yes

Special Water Heating System Assignments. In multi-unit buildings or buildings with more than one water heating system, it is necessary to assign water heating systems to the dwelling units that they serve. This is necessary in order for the recovery load to be properly calculated for each system. When an ACM models a

6 See Footnote 3, Page 2-22.

7 May be recovery efficiency, thermal efficiency, or AFUE.

water heating system that does not have a single separate water heater serving each dwelling unit, it must be reported in the *Special Features and Modeling Assumptions* listings of the CF-1R and the C-2R. The *Special Features and Modeling Assumptions* listing must cross-reference the listing below which must be included as part of the C-2R whenever multiple water heaters serve one or more dwelling units or when a single water heater serves more than one dwelling unit and is modeled by the ACM for compliance.

In the example below, the building has three water heating systems labeled "upper-floors", "lower-floors" and "kitchens". The "upper-floors" and "lower-floors" systems are both central gas water heaters with recirculating distribution systems. The kitchens in each dwelling unit have their own point of use instantaneous electric water heaters (all of which may be grouped together as one system).

SPECIAL WATER HEATING SYSTEM ASSIGNMENTS *(Example Listing)*

Number of Units	CFA per Unit	Name(s) of System(s)
8	1000	Upper Floors Kitchens
10	800	Lower Floors Kitchens

SPECIAL WATER HEATING SYSTEM ASSIGNMENTS *(Example Listing)*

Number of Units	CFA per Unit	Name(s) of System(s)
1	1800	Main

- Number of Units. The number of dwelling units served by this system assignment.
- CFA per Unit. The average conditioned floor area per dwelling unit in this system assignment.
- Name(s) of Systems(s). The water heating system names associated with this assignment. Names must correspond to system names defined in the Water Heating Systems table.

Special Features and Modeling Assumptions. This listing must **stand out and command the attention** of anyone reviewing this form to emphasize the importance of verifying these Special Features and the aspects of these features that were modeled to achieve compliance or the energy use results reported. This is a free format section for the C-2R report to note any special features about the building that are needed to verify compliance.

SPECIAL FEATURES AND MODELING ASSUMPTIONS: *(Example Listing)*

This house has zonal control and multiple zones,
This house uses a non-NAECA large storage gas water heater. Check the C-2R SPECIAL WATER HEATER/BOILER DETAILS listing for specifications.
This house has an attached sunspace with interzone surfaces, interzone ventilation, and custom solar heat distribution.

HERS Required Verification. Specific features that require diagnostic testing to assure proper installation require field testing and verification by a certified home energy rater under the supervision of a Commission-approved HERS provider, and must be listed in this section. This listing must **stand out and command the attention** of anyone reviewing this form to emphasize the importance of HERS verification of these features and the aspects of these features that were modeled to achieve compliance. or the energy use results reported.

HERS REQUIRED VERIFICATIONS *(Example Listing)*

This house is using an HVAC system with all ducts and the air handler located within the conditioned space. This results in a higher distribution efficiency rating and must be visually confirmed by a certified HERS rater under the supervision of a CEC-approved HERS provider. This verification must be reported on a CF-6R form.
This 1600 square foot house has tight construction with reduced infiltration and a target blower door test range of 586 to 1250 CFM at 50 pascals. The blower door test must be performed using the ASTM *Standard Test Method for Determining Air Leakage Rate by Fan Pressurization*, ASTM E 779-87 (Reapproved 1992).
WARNING: If this house tests below 586 CFM at 50 pascals, the house must either be provided with a ventilation opening that will increase the tested infiltration to at least 586 CFM at 50 pascals (SLA = 1.5) OR mechanical supply ventilation must be provided that can maintain the house at a pressure of at least -5 pascals relative the outside average air pressure while other continuous ventilation fans are operating.
WARNING - Houses modeled with reduced infiltration and/or mechanical unbalanced exhaust ventilation are prohibited from having vented combustion appliances that use indoor air for combustion inside conditioned space.

3. Defining the Proposed and Standard Designs

The space conditioning energy budget for the low-rise residential Standards is a custom budget, that is, the energy that would be used by a building similar to the *Proposed Design*, but that is modified to just meet the requirements of the prescriptive standards. The building that is modeled to create the custom budget is the *Standard Design*. This section of the *ACM Approval Manual* describes how the *Proposed and Standard Designs* are defined.

The *Proposed Design* is modeled based upon user inputs that are subject to a variety of restrictions as well as a variety of fixed and restricted assumptions regarding dwelling design and operation. The user enters information to describe the thermal characteristics of the building envelope including its surface areas, air leakage, shading structures and attachments, thermal mass elements, heating and cooling equipment and distribution systems, and water heating equipment and distribution systems.

The process of generating the *Standard Design* and calculating the custom budget must be performed automatically by the program based on the allowed and default inputs for the *Proposed Design* as well as the fixed and restricted inputs and assumptions for both designs. These operations shall not be accessible to program users for modification when the program is used for compliance purposes or when compliance forms can be generated by the program. The *Standard Design* generator must automatically take user input about the *Proposed Design* and create input data for the *Standard Design*, using all the applicable fixed and restricted inputs and assumptions. All assumptions and algorithms used to model the *Proposed Design* must also be used in a consistent manner in the *Standard Design* building.

Defining the *Standard Design* building involves two steps. First, the geometry of the proposed building is modified from the description entered for the proposed design. Second, building features are modified to meet the minimum requirements of compliance with package D of the Standards.

The following sections present the details on how the *Standard Design* is to be developed.

3.1 Basis of the Standard Design - Package D

The basis of the *Standard Design* is package D. The requirements of package D are contained in Section 151(f) of Title 24, Part 6 of the State Building Standards. These prescriptive requirements are not repeated here.

3.2 Building Physical Configuration

Proposed Design: The building configuration is defined by the user entries for heavy and light floor areas, wall areas, roof and ceiling areas, fenestration areas, and door areas, which are entered along with the orientation of these building elements. The user entries for all of these building elements must be consistent with the actual building design and configuration. If the ACM actually models the specific geometry of the building by using a coordinate system or graphic entry technique, the building geometry must be as consistent as reasonably possible with the actual building design to achieve thermal modeling accuracy.

Standard Design: The *Standard Design* building has the same floor area, volume, and configuration as the *Proposed Design*, except that wall and window area are distributed equally between the four main compass points, North, East, South, and West. The details are described below.

3.2.1 Conditioned Floor Area

Proposed Design: The ACM must require the user to enter the total conditioned floor area of the *Proposed Design* as well as the conditioned slab floor area. The conditioned slab floor area is the area of a slab floor with a minimum slab thickness of 3.5 inches or a minimum heat capacity of 7.0 Btu/ft^2-°F and conditioned space above and unconditioned space or the ground/gravel below. The non-slab conditioned floor area is the total conditioned floor area minus the conditioned slab floor area.

Standard Design: The total conditioned floor area and the conditioned slab floor area of the *Standard Design* building is the same as the *Proposed Design*.

Proposed Design & Standard Design: ACMs must keep track of the conditioned floor area and must at least be able to keep separate track of the total conditioned floor area and conditioned slab floor area. These areas are used to determine the default thermal mass for the *Proposed Design* and the thermal mass for the *Standard Design*. Stairwell floor area is the horizontal area of the stairs and landings between two floors of each story of the house. The conditioned slab floor area may be either on-grade or a raised slab.

3.2.2 Volume

Proposed Design: The volume of the *Proposed Design* is the conditioned volume of air enclosed by the building envelope. The volume must be consistent with the air volume of the actual design and may be determined from the total conditioned floor area and the average height or from a direct user entry for volume.

Standard Design: The volume of the *Standard Design* building is the same as the *Proposed Design*.

3.2.3 Ceilings

Proposed Design: The ACM shall allow a user to enter one or more ceiling/roof areas for the *Proposed Design* from an approved list of roof/ceiling construction types. Some of these construction types may be user-defined but the ACM must determine the output names for user-defined construction types for all building envelope constructions. The ACM shall not allow the user to specify output names for construction types or envelope elements. The roof/ceiling areas, construction assemblies, and tilts modeled must be consistent with the corresponding areas, construction assemblies, and tilts in the actual building design and must total the overall roof/ceiling area with conditioned space on the inside and unconditioned space on the other side. Except as indicated in the next sentence, the U-value of the modeled assembly must be the same as the U-value of the actual assembly. Ceiling construction assemblies that do not meet the mandatory minimum U-value required by Title 24 shall not be allowed.

Standard Design: The ceiling/roof areas of the *Standard Design* building are equal to the ceiling/roof areas of the *Proposed Design*. The *Standard Design* roof and ceiling surfaces are assumed to be horizontal (no tilts) and have a U-value specific to the package D requirements. The *Standard Design* generator must consider all exterior surfaces in the *Proposed Design* with a tilt less than 60 degrees as roof elements. Surfaces that tilt 60 degrees or more are treated as walls.

3.2.4 Radiant Barriers

Proposed Design: The ACM must allow the user to input a radiant barrier. The presence of a radiant barrier must be reported in the *Special Features and Modeling Assumptions* listings on the CF-1R and C-2R.

Standard Design: The *Standard Design* shall have a radiant barrier in accordance with Package D requirements.

3.2.5 Cool Roofs

Proposed Design: The ACM must allow the user to input a cool roof. The presence of a cool roof must be reported in the *Special Features and Modeling Assumptions* listings on the CF-1R and C-2R.

Standard Design: The *Standard Design* shall be modeled without a cool roof.

3.2.6 Walls

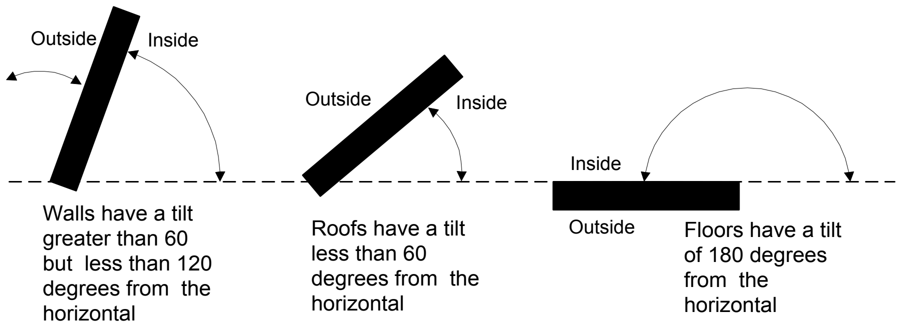


Figure 3-1 - Surface Definitions

Proposed Design: The ACM shall allow a user to enter one or more wall areas for the *Proposed Design* from an approved list of wall construction types. Some of these construction types may be user-defined but the ACM must determine the name for user-defined construction types for all building envelope constructions. The ACM shall not allow the user to specify names for construction types or envelope elements. The wall areas modeled must be consistent with the corresponding wall areas in the actual building design and the total wall area must be equal to the gross wall area with conditioned space on the inside and unconditioned space or exterior conditions on the other side.

Standard Design: The gross wall area in the *Standard Design* run is equal to the gross wall area of the *Proposed Design*, including knee walls in the ceiling construction of the *Proposed Design*. The gross wall area in the *Standard Design* is equally divided between the four main compass points, North, East, South, and West. Window and door areas are subtracted from the gross wall area to determine the net wall area in each orientation. All surfaces included in the *Proposed Design* run input file with a tilt from the horizontal of 60 degrees or more and less than 120 degrees are treated as walls. Surfaces that have a tilt of less than 60 degrees are considered to be roof surfaces.

3.2.7 Basement Walls and Floors

Proposed Design: Portions of basement walls above grade must be modeled as conventional walls above grade. The user must be requested to enter the area of basement walls below grade as the area of below grade wall at each of 3 depths for Zero to 2 feet below grade (shallow), greater than 2 feet to 6 feet below grade (medium), and greater than 6 feet below grade (deep). The ACM shall allow users to enter as many wall types as necessary to model the proposed construction. The ACM must use the same method for determining the U-value and mass characteristics for below grade walls as used for above grade walls. The default value for the proposed design wall construction shall be the same as the *Standard Design*.

Standard Design: The *Standard Design* shall have the same basement wall areas as the *Proposed Design*. The *Standard Design* basement wall shall be assumed to be a wall with a Heat Capacity of 15.7 Btu/(ft^2-^{o}F), a thickness of 8 inches, and an uniform R-value of 1.5.

3.2.8 Floors

Proposed Design: In addition to the total conditioned floor area and total conditioned slab floor area, ACMs must allow the user to enter floor areas for the standard raised floor construction types listed in Table R3-1 and at least three user-defined construction types. The ACM must require user input to be able to distinguish floor areas and constructions that are over crawl spaces. The ACM and its documentation must inform the user that the floor constructions and areas must be consistent with the actual building design.

The effect of a conventional crawl space is approximated with a thermal resistance of R-6; however, for controlled ventilation crawl spaces (an optional capability), the crawl space is modeled as a separate thermal zone and R-6 is not assumed. The R-6 value for a conventional crawlspace shall be automatically calculated by the ACM and shall not be allowed as a user input.

Standard Design: The exposed raised floor U-value used in the *Standard Design* is independent of the proposed construction assembly. It does vary, however, depending on whether or not the floor assembly is located over a crawl space. The ACM must keep track of which raised floor surfaces are over crawl spaces and which are not.

Proposed Design & Standard Design: The effect of a crawl space is approximated with a thermal resistance of R-6 and this is accounted for in the *Standard Design* U-value in Table R3-1. Raised floors in the *Proposed Design* that are not located over a crawl space shall not include the R-6 thermal resistance used for floors over a crawl space.

3.2.9 Slab-on-Grade Perimeter

Proposed Design: The ACM must allow users to enter at least two different slab perimeter constructions and their corresponding lengths. ACMs must assume that 80% of any slab edge length entered is adjacent to rug-covered (R-2 for carpet and pad) slab and 20% is adjacent to exposed slab on the conditioned side and determine an overall F2 factor for the total length or specify that the user enter or choose such a weighted F2 factor. The ACM must be able to determine the amount of slab edge adjacent to unconditioned spaces separately from the slab edge adjacent to the outside so that the ACM can determine the appropriate *Standard Design*. In the *Proposed Design*, the F2 factor(s) may account for slab perimeter insulation for both slab edges exposed to the outside and slab edges adjacent to unconditioned spaces such as garages. Slab edges adjacent to garages and unconditioned spaces may be considered to be insulated with R-7 insulation and have an F2 factor of 0.51.

Standard Design: The total slab perimeter length in the *Standard Design* is the same as in the *Proposed Design*. For the *Standard Design,* the slab edge heat loss factor, F2, is 0.76 for all climate zones except Climate Zone 16 where F2 is 0.51. For the *Standard Design* unconditioned spaces such as the garage are assumed to be detached, hence the slab perimeter between conditioned spaces and unconditioned spaces such as garages is assumed to meet the Alternative Component Package D requirements in Section 151 of the building efficiency standards and is assumed to be exposed to the outside conditions. See Section 4.7.1 for details.

3.2.10 Doors

Proposed Design: ACMs must allow users to enter at least two different door construction types, their areas, and orientations. These door types must include the standard door type specified in Table R3-1 plus at least one user-defined door type with an ACM specified name or designator. For the user-defined door type, the ACM must at least allow the user to enter the area, the orientation, and the U-value or R-value of the door.

Standard Design: The *Standard Design* has 40 square feet of door area for each dwelling unit. All doors are assumed to face north. This means that the net opaque wall area facing north is reduced 40 ft^2 for each dwelling unit for the *Standard Design* run.

3.2.11 Fenestration Types and Areas[8]

Proposed Design: ACMs must allow users to select fenestration or window types from the default tables in the standards or from several user-defined fenestration types where the user must enter the *Number of Fenestration Assemblies*, the *U-value* and *Solar Heat Gain Coefficient (SHGC)* for any user-defined window type. For each user-defined fenestration type the ACM must require the user to enter the Fenestration Area, tilt and orientation.

Standard Design: ~~Fenestration area in the *Standard Design* is determined by the package D specification for the appropriate climate zone. If package D for the climate zone permits 20% of the conditioned floor area in glass, then the *Standard Design* has a fenestration area equal to 5% of the conditioned floor area facing in the direction of each major compass point. If package D for the climate zone permits 16% of the conditioned floor area in glass, then the Standard Design has a fenestration area equal to 4% of the conditioned floor area~~

---

8 The justification for this change appears in Eley Associates, "Residential Fenestration," *Measure Analysis and Life-Cycle Cost: 2005 California Building Energy Efficiency Standards, Part II*, May 16, 2002, p. 4-13. Presented at the May 30, 2002 workshop.

~~facing in the direction of each major compass point.~~ If the *Proposed Design* fenestration area is less than the package D specification, the *Standard Design* fenestration area is set equal to the *Proposed Design* fenestration area. Otherwise, the *Standard Design* fenestration area is equal to the package D specification. The *Standard Design* fenestration area is distributed equally between the four main compass points—North, East, South and West. There is no skylight area in the *Standard Design* run. The net wall area on each orientation is reduced by the fenestration area (and door area) on each facade.

3.2.12 Overhangs

Proposed Design: ACMs must allow users to enter a set of basic generic parameters for a description of an overhang for each individual fenestration or window area entry. The basic parameters must include *Fenestration Height, Fenestration Width, Overhang Length, and Overhang Height.* ACM user entries for overhangs may also include *Overhang Left Extension* and *Overhang Right Extension.*

Standard Design: The *Standard Design* does not have overhangs.

3.2.13 Fan Energy[9]

Proposed Design: The ACM must allow the user to specify whether or not the proposed design will take credit for reduced fan Watts, see 4.28. The credit for reduced fan Watts must be reported in the Special Features and Modeling Assumptions listings on the CF-1R and C-2R.

Standard Design: The *Standard Design* shall have the default fan watts.

3.2 Envelope Heat Loss Factors and Insulation Installation Quality

3.2.1 Heat Loss Factors

Heat loss factors include U-values for ceilings/roofs, walls, floors, windows and doors. For the slab edges of slabs-on-grade the heat loss factor is expressed as an F2 factor

Proposed Design: Except for user-defined walls, ACMs must automatically assign heat loss factors based on the user's selection of one of the standard building elements from the approved lists of standard building elements.

ACM vendors should note that user entered U-values are developed with an outside air film resistance of 0.17 based on a 15 mph wind speed. The vendors may internally adjust the U-value in the simulation for average wind conditions (3 mph wind) by assuming an outside air film resistance of 0.38 or they may strip off the fixed outside air film R-value of 0.17 and calculate an hourly R-value for the outside air film coefficient based on the wind speed and surface roughness.

Standard Design: Heat loss factors in the *Standard Design* are determined by the Package D specification. They are independent of the construction assembly in the proposed building. The heat loss factors used in the *Standard Design* are given in the table below. The *Standard Design* U-values for roof/ceilings and walls depends only on the package specification and is independent of the actual construction assembly proposed. The standard design U-values include an external air film with an R-value of 0.17 based on a 15 mile per hour wind speed. The adjustment to this air film for the standard design shall be the same as that used for the proposed design.

For slab edges, the heat loss factor (F2 factor) is one of two fixed values in the *Standard Design* run. For climate zones with no slab edge insulation requirement and slab edges adjacent to unconditioned spaces F2 is 0.76 and for slab edges required to be insulated it is 0.51. For the climate zone package(s) that require slab edge insulation (Climate Zone 16), the slab edge for the *Standard Design* has insulation on the total perimeter length and has an F2 factor of 0.51.

The door U-value is fixed at 0.330 Btu/(hr-ft^2-°F) in the *Standard Design* run.

---

9 The justification for this change appears in Eley Associates, "Residential Ducts," *Measure Analysis and Life-Cycle Cost: 2005 California Building Energy Efficiency Standards, Part III*, July 3, 2002, p. 17-66. Presented at the July 18, 2002 workshop.

3.2.2 Insulation Installation Quality[10]

Proposed Design: The default is standard insulation installation quality. ACMs must allow the user to specify High Quality Insulation Installation for the proposed design. The presence of High Quality Insulation Installation must be reported in the *Special Features and Modeling Assumptions* listings on the CF-1R and C-2R. High Quality Insulation Installation must be certified by the installer and verified by a rater.

Standard Design: The Standard Design shall have standard insulation installation quality.

Table R3-1 - Basecase Heat Loss Factors

Building Component	Package Specification or Mandatory Minimum	U-value
Roof	R-19	0.051
	R-30	0.034
	R-38	0.028
Wall	R-13	0.088
	R-19	0.065
	R-21	0.059
Raised Concrete Floor	R-0	
	R-4	
	R-8	
Raised Floor (crawl space)	R-19	0.037
(no crawl space)	R-19	0.049
Fenestration	U = 0.75	0.75
	U = 0.65	0.65
	U = 0.60	0.60
Doors	na.	0.330
		F2 Factor[1]
Slab Edge	None	0.76
	R-7	0.51

[1] The F2 Factor is determined based on the required assumption that 80% of the slab edge is adjacent to rug-covered slab and 20% is adjacent to exposed slab.

3.3 Solar Heat Gain Coefficients

Proposed Design: ACMs must require the user to enter the fenestration Solar Heat Gain Coefficient for each window, skylight, or other fenestration system type with a separate area. This requirement may be met by having the user select from a standard list of fenestration systems and sizes or by direct entry for user-defined windows or skylights. In addition, for each window, skylight and fenestration element the ACM must require the user to select an exterior shading treatment from the lists given in Table R3-3. The ACM will then determine the overall SHGC for the complete fenestration system based on the fenestration SHGC and the SHGCs assigned to the Commission-approved exterior shading devices and assigned interior shading devices from Table R3-2 and Table R3-3.

Standard Design: The *Standard Design* fenestration Solar Heat Gain Coefficients (SHGCs) are determined by the appropriate Package D specifications for the applicable climate zone. Note that the frame type and the

[10] The justification for this change appears in Reference the revised Construction Quality paper to be completed the week of 10/13.

presence or absence of muntins or dividers is irrelevant for the *Standard Design* as the Package D values for $SHGC_{fen}$ and the U-factor include the effects of fenestration features such as framing, dividers, and muntins.

3.4 Shading Devices and their Solar Heat Gain Coefficients

Internally, ACMs shall use two values to calculate solar heat gain through windows: $SHGC_{open}$ and $SHGC_{closed}$. $SHGC_{open}$ is the total solar heat gain coefficient of the fenestration and its exterior shading device when the operable interior shading device is open. $SHGC_{closed}$ is the total solar heat gain coefficient when the interior shading device is closed. $SHGC_{open}$ is the setting that applies when the air conditioner is not operating, which typically is most of the 24-hour period, while $SHGC_{closed}$ applies only for periods when the air conditioner operates. The *Standard Design* values for these SHGCs are shown in Table R3-4 below. $SHGC_{open}$ and $SHGC_{closed}$ are not user specified inputs.

The ACM must require the user to directly or indirectly specify $SHGC_{fen}$ and frame type. The ACM must assign an interior shading device as listed in Table R3-2 and require the user to specify exterior shading device as listed in Table R3-3. The ACMs must calculate the overall SHGC for the fenestration with shading devices as shown in Chapter 4.

For both the *Proposed Design* and the *Standard Design,* all windows are assumed to have draperies and skylights are assumed to have no interior shading. The ACM Compliance Supplement must also explicitly indicate that the ACM automatically gives credit for draperies for all windows and that credit is allowed only for one exterior shading device.

Proposed Design: The ACM must require the user to either accept the default exterior shading device or select from a specific Commission-approved list of exterior shading devices for each fenestration element. The interior shading device is *Standard* (0.68 SHGC) for windows and *None* (1.0 SHGC) for skylights. The default choice for exterior shading device is *Standard,* which is assigned an average SHGC of 0.76

Standard Design: The ACM uses the default values for interior and exterior shading devices for the *Standard Design* based on *Standard* for windows and *None* for skylights from Table R3-2 and Table R3-3.

Table R3-2 - Allowed Interior Shading Devices and Recommended Descriptors

Recommended Descriptor	Interior Shading Attachment Reference	Solar Heat Gain Coefficient
Standard	Draperies or No Special Interior Shading - Default Interior Shade	0.68 1
None 2	No Interior Shading - Only for Skylights (Fenestration tilt <60 degrees)	1.00
Note (general): No other interior shading devices or attachments are allowed credit for compliance with the building efficiency standards. Note 1: Standard shading shall be assumed for all fenestration with a tilt of 60 degrees or greater from horizontal. Note 2: *None* is the default interior shading device in the standard and proposed design for fenestration tilted less than 60 degrees from horizontal (skylights) and is only allowed for fenestration tilted less than 60 degrees from horizontal (skylights), i.e. *None* is not an interior shading option for ordinary vertical windows		

Table R3-3 - Allowed Exterior Shading Devices and Recommended Descriptors

Recommended Descriptor	Exterior Shading Device Reference	Solar Heat Gain Coefficient
Standard	Bug Screen or No Shading - Default Bugscreens are modeled	0.76
WvnScrn	Woven SunScreen (SC<0.35)	0.30
LvrScrn	Louvered Sunscreen	0.27
LSASnScrn	LSA Sunscreen	0.13
RlDwnAwng	Roll-down Awning	0.13
RlDwnBlnds	Roll -down Blinds or Slats	0.13
None 1	For skylights only - No exterior shading	1.00
Note 1: *None* is the default for fenestration tilted less than 60 degrees from horizontal (skylights) and is only allowed for fenestration tilted less than 60 degrees from horizontal (skylights)., i.e. *None* is not an exterior shading option for ordinary vertical windows.		

Table R3-4 - Standard Design *Shading Conditions*

	Package Specification	
Characteristic	**$SHGC_{fen}$ = NR**	**$SHGC_{fen}$ = 0.40**
$SHGC_{fen}$	0.70	0.40
$SHGC_{open}$	0.68	0.39
$SHGC_{closed}$	0.63	0.37
Glazing	Double Clear	Double Clear
$SHGC_{fen+int}$	0.647	0.378
Interior Shade	Drapes (*Standard*)	Drapes (*Standard*)
$SHGC_{int}$	0.68	0.68
Exterior Shade	Bugscreen (*Standard*)	BugScreen (*Standard*)
$SHGC_{ext}$	0.76	0.76

3.5 Thermal Mass

The performance approach is based on prescriptive Package D of the efficiency standards, which has no thermal mass requirements. Package D and the performance approach assume that both the *Proposed Design* and *Standard Design* building have a minimum mass as a function of the conditioned area of slab floor and nonslab floor.

Proposed Design: The ACM may require the user to identify whether or not the *Proposed Design* is a high mass building that exceeds the specified mass threshold. Unless the *Proposed Design* has thermal mass that exceeds a thermal mass minimum threshold, the ACM shall model thermal mass for *the Proposed Design* the same as the *Standard Design*.

Standard Design: The ACM shall model the *Standard Design* as 20 percent of the *Proposed Design*'s conditioned slab floor area as exposed slab, 80% of the conditioned slab floor area as rug-covered slab, and 5% of the *Proposed Design*'s nonslab floor area as exposed 2 inch thick concrete. No other mass elements are modeled in the *Standard Design*.

The conditioned slab floor area (slab area) shall be modeled as 20 percent exposed thermal mass having a thickness of 3.5 inches, a volumetric heat capacity of 28 Btu/ft^3-°F, a conductivity of 0.98 Btu-in/hr-ft^2-°F, and a surface conductance of 1.3 Btu/hr-ft^2-°F (no thermal resistance on the surface). The remaining 80% of the conditioned slab floor area shall be modeled as covered thermal mass with the same characteristics as the exposed mass, but with the addition of a surface R-value of 2.0 Btu/hr-ft^2-°F typical of a carpet and pad.

Conditioned nonslab floor area shall be modeled with 5% of the nonslab floor area as exposed thermal mass. This thermal mass is modeled in both the *Proposed Design* and *Standard Design* with a thickness of 2.0 inches, a volumetric heat capacity of 28 Btu/ft^3-°F, a conductivity of 0.98 Btu-in/hr-ft^2-°F, a surface conductance of 1.3 Btu/hr-ft^2-°F (no added thermal resistance on the surface).

3.6 High Mass Threshold

Proposed Design: The ACM may only allow the user to model additional thermal mass when the equivalent thermal mass for the *Proposed Design* reaches a specific mass threshold. The ACM may require that a user indicate a high mass design before the user is allowed to enter additional mass elements and mass characteristics other than what is assumed for the *Standard Design*. The high mass threshold is determined by an amount of mass equivalent to 30% of the conditioned slab floor area as exposed slab, 70% of the conditioned slab floor area as rug-covered slab and 15% of the conditioned nonslab floor area as 2 inch thick exposed concrete with the same specifications as those given in the ***Thermal Mass*** section above. To determine the threshold, this mass is converted to a standard Interior Mass Capacity using the Unit Interior Mass Capacity (UIMC) method described in Appendix I.

The thermal mass of the *Proposed Design,* other than the mass modeled for the *Standard Design* is only modeled and displayed on compliance output if the design has more equivalent thermal mass than the high mass threshold. The ACM may require that the user specify that the design is a high mass design before the entry of mass elements not related to the slab floor and nonslab floor defaults. For example, a *Proposed Design* with all of the conditioned floor area as slab-on-grade construction designed with 25% exposed slab is still modeled with 20% exposed slab because the designed thermal mass does not exceed the threshold. If the same house is designed with 30% of the conditioned floor area as exposed slab and 70% rug-covered slab then the permit applicant may model that amount of thermal mass in the *Proposed Design*. In addition, a *Proposed Design* may model and take credit for other forms of thermal mass such as masonry fireplaces or extra-thick sheetrock using the UIMC method to determine if the threshold mass is reached. Additional mass elements are not modeled in the *Standard Design*.

Standard Design: The *Standard Design* thermal mass is the same as described in Section 3.6.

3.7 Heating and Cooling System

Proposed Design: ACMs must require the user to enter simple heating and cooling seasonal efficiencies that are used to characterize basic package single zone HVAC systems used to heat and/or cool the modeled building. ACMs must be able to distinguish what fuel is being used to heat the building and what fuel is used to cool the dwelling. This may be based on direct user input or indirectly determined from the user's selection of HVAC equipment types. ACMs must require the user to enter the type of distribution system that is used in the proposed design.

Standard Design: The standard heating and cooling system for central HVAC systems is a single zone system with ducts in the attic. The standard heating and cooling system for non-central HVAC systems is an unducted system.

3.7.1 Heating Equipment

Proposed Design: ACMs must be able to model the basic types of heating equipment listed in Table R 2-3 except for combined hydronic space and water heating systems, which is an optional modeling capability. ACMs must require the user to enter the basic information to model the energy use of these pieces of equipment. At the minimum this includes some type of seasonal efficiency for heating and whether or not the HVAC system has ducts. When using a gas heating system, the ACM must require the user to identify if the gas heating system is ducted or non-ducted and if it is a central gas furnace or gas heat pump system, or a non-central gas furnace system. If the system is a non-ducted non-central gas furnace system, the ACM must require the user to select the type and size of the equipment from Table R3-5 where the system size, as a default, may be determined as 34 Btu/hour per square foot of conditioned floor area. ~~For central ducted systems the ACM *Proposed Design* shall use Equation 3.2 for gas furnaces, 3.4h for gas heat pumps, and 3.3 for electric heat pumps and electric resistance furnaces.~~[11]

Table R3-5 - Non-Ducted Non-Central Heating Equipment Default Efficiencies

Gas Fired Wall Furnaces, Floor Furnaces and Room Heaters			**Seasonal Efficiency**
Wall	fan type	up to 42,000 Btu/hour	73%
		over 42,000 Btu/hour	74%
	gravity type	up to 10,000 Btu/hour	59%
		over 10,000 Btu/hour up to 12,000 Btu/hour	60%
		over 12,000 Btu/hour up to 15,000 Btu/hour	61%
		over 15,000 Btu/hour up to 19,000 Btu/hour	62%
		over 19,000 Btu/hour up to 27,000 Btu/hour	63%
		over 27,000 Btu/hour up to 46,000 Btu/hour	64%
		over 46,000 Btu/hour	65%
Floor		up to 37,000 Btu/hour	56%
		over 37,000 Btu/hour	57%
Room		up to 18,000 Btu/hour	57%
		over 18,000 Btu/hour up to 20,000 Btu/hour	58%
		over 20,000 Btu/hour up to 27,000 Btu/hour	63%
		over 27,000 Btu/hour up to 46,000 Btu/hour	64%
		over 46,000 Btu/hour	65%

Standard Design: When electricity is used for heating, the heating equipment for the *Standard Design* shall be an electric heat pump with a Heating Seasonal Performance Factor (HSPF) of 6.8 except when *Proposed Design*s use a single package heat pump only, the *Standard Design* shall assume an HSPF of 6.6. When electricity is not used for heating, the equipment used in the *Standard Design* building shall be either a gas furnace with an Annual Fuel Utilization Efficiency (AFUE) of 0.78 for central systems, or shall be a gas furnace of the type specified in the proposed design at the efficiency level shown in Table R3-5 for non-central systems. ~~If the *Proposed Design* has both electric and fossil-fuel-fired heating equipment types, the standard system shall be based on the floor area weighted Source Seasonal Efficiency (SSE). In calculating the weighted average SSE, the efficiencies of all heating equipment and distribution systems are converted to source seasonal efficiencies (SSE), as shown in Equations 3.2 and 3.3.~~

~~Seasonal air distribution efficiencies ($\eta_{dist,\ seasonal}$) for the *Proposed Design* and the *Standard Design* shall be calculated using the procedures and algorithms in Appendix F, and Equation 3.1. The seasonal distribution efficiencies for the *Standard Design* shall be calculated using the defaults specified in Appendix F. The seasonal distribution system efficiency shall be calculated using the seasonal delivery effectiveness ($DE_{seasonal}$), the equipment efficiency factor (F_{equip}), and the thermal recovery factor (F_{recov})~~

$$\cancel{\eta_{dist,\,seasonal} = 0.98 \times DE_{seasonal} \times F_{equip} \times F_{recov}}$$

~~Equation 3.1~~

[11] This material is now included in ACM chapter 4

$$SSE_{\text{gas with fan}} = \left(\frac{1 + (0.005 \times 3.413)}{\frac{1}{AFUE} + (0.005 \times 10.239)} \right) \times \eta_{dist,seasonal}$$ ~~Equation 3.2~~

$$SSE_{electric} = \left(\frac{HSPF}{10.239} \right) \times \eta_{dist,\ seasonal}$$ ~~Equation 3.3~~

$$SSE_{\text{GasHeatPump,Heating}} = \frac{\eta_{dist,seasonal}}{\left[\frac{1}{COP_{heatinggas}} + \frac{3}{COP_{heatingelectric}} \right]}$$ ~~Equation 3.4h~~

3.7.2 Cooling Equipment

Proposed Design: ACMs must be able to model the basic types of cooling equipment listed in Table R 2-3. ACMs must require the user to enter the basic information to model the energy use of these pieces of equipment. At the minimum this includes some type of seasonal distribution system efficiency for cooling, identification of whether the cooling system is ducted or non-ducted and central or non-central. If the cooling system is non-ducted non-central, the ACM must require the user to select the type and size of the equipment from those shown in Table R3-6. ~~The efficiencies of all electric cooling equipment and distribution systems are converted to source seasonal energy efficiency ratios (SSEER), as shown in Equations 3.2c and 3.3c. The efficiencies of all gas cooling equipment and distribution systems are converted to source seasonal efficiency as shown in Equations 3.4c. Packaged air conditioning systems (PkgAirCond, LrgPkgAirCond, PkgHeatPump or LrgPkgHeatPump) shall be noted in the Special Features and Modeling Assumptions listings.~~

Table R3-6 - Non-Ducted Non-Central Cooling Equipment Default Efficiencies

Room Air Conditioner Type		**Cooling Capacity**	**Energy Efficiency Ratio**
Reverse Cycle	**Side Louvers**		
Without	with	less than 6,000 Btu	8.0
		6,000 to 7,999 Btu	8.5
		8,000 to 13,999 Btu	9.0
		14,000 to 19,999 Btu	8.8
		20,000 and more Btu	8.2
	without	less than 6,000 Btu	8.0
		6,000 to 7,999 Btu	8.5
		8,000 to 13,999 Btu	8.5
		14,000 to 19,999 Btu	8.5
		20,000 and more Btu	8.2
With	with	All	8.5
	without	All	8.0

Standard Design: If a packaged ducted central air conditioner (*PkgAirCond* or *LrgPkgAirCond*) or ducted central packaged heat pump (*PkgHeatPump* or *LrgPkgHeatPump*) is used for the *Proposed Design*, the cooling system used in the *Standard Design* building shall be a single package air conditioner (*PkgAirCond* or *LrgPkgAirCond*) with an SEER (seasonal energy efficiency ratio) of 9.7. Otherwise, the cooling system for the *Standard Design* building with a central system shall be a split system central air conditioner *(SplitAirCond)* with an SEER of 10.0. For non-ducted non-central cooling equipment, the efficiencies shall be as shown in Table R3-6 for the type and size in the *Proposed Design* where the size may be a user input or shall default to 24 Btu per hour per square foot of conditioned floor area. In the case of *NoCooling* for the *Proposed Design*, the cooling system for the *Standard Design* building shall be a split system air conditioner (*SplitAirCond*) with an SEER of 10.0. When a *Proposed Design* uses both a split system air conditioner and another type of air conditioner, the *Standard Design* SEER shall be a conditioned floor area weighted average of the equivalent SEER of the cooling equipment. [12]~~The efficiencies of all electric cooling equipment and distribution systems are converted to source seasonal energy efficiency ratios (SSEER), as shown in Equations 3.2c and 3.3c. The efficiencies for gas cooling equipment and distribution systems are converted to source seasonal efficiency~~ ~~($SSE_{GasHeatpumCooling}$) as shown in Equation 3.4c~~

~~Seasonal air distribution efficiencies ($\eta_{dist, seasonal}$) for the *Proposed Design* and the *Standard Design* shall be calculated using the procedures and algorithms in Appendix F. The seasonal distribution efficiencies for the *Standard Design* shall be calculated using the defaults specified in Appendix F. The seasonal distribution system efficiency shall be calculated using the seasonal delivery effectiveness ($DE_{seasonal}$), the equipment efficiency factor (F_{equip}), and the thermal recovery factor (F_{recov})~~

~~Source seasonal energy efficiency ratios for the *Standard Design* shall be calculated as shown in Equations 3.1c, 3.2c and 3.3c.~~

$$\cancel{\eta_{dist,seasonal} = 0.98 \times DE_{seasonal} \times F_{equip} \times F_{recov}}$$ ~~Equation 3.1c~~

$$\cancel{SSEER_{central,ducted} = SEER_{temperature} \times F_{install} \times F_{TXV} \times \eta_{dist,seasonal}}$$ ~~Equation 3.2c~~

$$\cancel{SSEER_{other} = SEER \times \eta_{dist,seasonal}}$$ ~~Equation 3.3c~~

---

12 This Material is now included in ACM Chapter 4.

$$SSE_{\text{GasHeatPump,Cooling}} = \frac{F_{install} \times F_{TXV} \times \eta_{dist,seasonal}}{\left[\frac{1}{COP_{coolinggas}} + \frac{3}{COP_{coolingelectric}}\right]}$$ ~~Equation 3.4c~~

~~The temperature adjusted SEER (SEER~~$_{temperature}$~~) adjusts the performance of the cooling equipment at typical outdoor air temperatures by climate zone depending on the SEER rating. For *SplitAirCond, PkgAirCond, SplitHeatPump, PkgHeatPump*, SEER~~$_{temperature}$~~ shall be interpolated from Table 3.6c. Extrapolation shall not be used with this table. Equipment with a SEER below 8 shall use the value for 8. Equipment with a SEER above 18 shall use the value for 18. For all other central ducted equipment, SEER~~$_{temperature}$~~ shall be equal to the EER rating.~~

~~Table 3.6c -- Temperature adjusted SEER (SEER~~$_{temperature}$~~) by Climate Zone~~

	SEER										
CZ	8	9	10	11	12	13	14	15	16	17	18
1	8.00	9.00	10.00	11.00	12.00	13.00	14.00	15.00	16.00	17.00	18.00
2	7.79	8.75	9.71	10.67	11.52	12.25	12.96	13.65	14.34	15.00	15.66
3	7.82	8.78	9.75	10.72	11.59	12.37	13.13	13.89	14.63	15.36	16.08
4	7.82	8.78	9.75	10.72	11.59	12.37	13.13	13.89	14.63	15.36	16.08
5	7.94	8.92	9.91	10.90	11.86	12.78	13.70	14.61	15.53	16.44	17.34
6	7.98	8.98	9.98	10.97	11.96	12.94	13.92	14.90	15.88	16.85	17.83
7	7.95	8.94	9.93	10.92	11.89	12.83	13.77	14.71	15.65	16.58	17.52
8	7.72	8.67	9.62	10.57	11.38	12.05	12.70	13.34	13.97	14.60	15.21
9	7.57	8.49	9.41	10.33	11.04	11.53	12.00	12.45	12.89	13.31	13.72
10	7.44	8.33	9.23	10.13	10.76	11.11	11.44	11.76	12.07	12.36	12.64
11	7.38	8.27	9.16	10.04	10.64	10.94	11.22	11.48	11.74	11.99	12.22
12	7.43	8.33	9.22	10.12	10.74	11.08	11.41	11.72	12.01	12.29	12.56
13	7.35	8.23	9.11	10.00	10.57	10.83	11.08	11.31	11.53	11.74	11.95
14	7.16	8.01	8.85	9.70	10.16	10.24	10.31	10.38	10.45	10.51	10.58
15	7.17	8.02	8.87	9.71	10.18	10.26	10.34	10.41	10.48	10.54	10.61
16	7.78	8.74	9.70	10.65	11.51	12.24	12.97	13.68	14.39	15.09	15.79

~~The installation factor (F~~$_{install}$~~), which adjusts for typical installation practice where refrigerant charge and airflow are not at design values, shall be 0.852.~~

~~The refrigerant charge and airflow factor (F~~$_{TXV}$~~), which adjusts the system performance to account for the presence of a TXV, shall be 1.0 for systems without a TXV. For systems with a TXV, the refrigerant charge and airflow factor shall be 1.07 for duct systems designed according to ACCA Manual D and 1.11 for all other duct systems.~~

3.7.3 Refrigerant Charge or TXV[13]~~and Airflow~~

Proposed Design: The ACM must allow the user to enter a central ducted cooling system with a refrigerant charge ~~and airflow~~measurement or TXV option which requires either measuring charge ~~and airflow~~ using procedures set forth in Appendix K (for split system equipment only) or requires the presence of a thermostatic expansion valve (TXV). These features require verification by the HERS rater and must be reported in the *Special Features and Modeling Assumptions and HERS Required Verification* listings on the CF-1R and C-2R.

Standard Design: Standard Design: If a split system ducted central air conditioner or heat pump (*SplitAirCond* or *SplitHeatPump*) is used for the *Proposed Design* then the cooling system used in the *Standard Design* building shall have either refrigerant charge ~~and airflow~~ measurement or be equipped with a thermostatic expansion valve if required by Package D.

~~Adjustments to the source seasonal energy efficiency ratio due to refrigerant charge and airflow measurement or thermostatic expansion valves are described in section 3.8.2.~~

3.7.4 Ducts and HVAC Seasonal Distribution System Efficiency for Ducted Systems

Proposed Design: As a default, HVAC ducts for ducted systems are assumed to exist and are located in the attic. Likewise, as a default, the air handler is assumed to be located in the attic. Proposed HVAC systems with a duct layout and design on the plans may locate the ducts in the crawlspace or a basement if the layout and design specify that all of the supply registers are located in the floor and show the appropriate locations for the ducts. When all of the supply registers are located in the floor or all of the supply registers are located in the ceiling, the ACM can use Table 4.1 of Appendix F to allocate the duct surface areas. If all supply registers are in the floor, but the building has both a crawlspace and a basement, the duct location may be taken as a floor area weighted average of the entries in Table 4.1 of Appendix F. If any story of a building has supply registers in both the floor and more than two feet above the floor, the duct location for that story must be modeled as 100% ducts in the attic. If the modeled duct location for a given story is not in the attic, the ACM must specify that all supply registers for that story of the building (or the whole building) are located in the floor in the *Special Features and Modeling Assumptions* listings for special verification by the local enforcement agency.

Proposed HVAC systems with a complete ~~ACCA Manual D~~duct design including the duct layout and design on the plans may allocate duct surface area in more detail in the ACM model but the distribution of duct surface areas by location must appear on the *HERS Required Verification* list for verification by a HERS rater.

~~In a similar fashion, the supply duct surface area (and the location of the ducts) of an ACCA Manual D designed duct system may be modeled explicitly in the ACM and receive energy efficiency credit. When a non-default supply duct surface area is modeled, the supply duct surface area is subject to verification by a HERS rater and must be listed on the *HERS Required Verification* listings.~~ The HERS rater must also verify the existence of ~~the ACCA Manual D~~ duct design and layout and the general consistency of the actual HVAC distribution system with the design. The HERS rater must also measure and verify adequate ~~the~~ fan flow, see Section 4.28.~~ and confirm that it is consistent with the ACCA Manual D design specifications.~~

The ACM shall allow users to specify if they will be using diagnostic testing of HVAC distribution efficiency of a fully-ducted system by a HERS rater during the construction of the building to confirm the modeling of improved HVAC distribution efficiency measures such as duct leakage. The default shall be that no diagnostic testing will be done. Duct efficiency credits may not be taken and diagnostic testing may not be done on any HVAC system that uses building cavities such as plenums or a platform return. If the user does not select diagnostic testing, the ACM shall require users to input at least two (2) basic parameters to determine HVAC distribution efficiency: the total conditioned floor area of the building as specified above and the R-value of the duct insulation which may be defaulted to R4.2. Additional data may be required to determine seasonal distribution

---

[13] 13 The justification for this change appears in Eley Associates, "Residential Ducts," *Measure Analysis and Life-Cycle Cost: 2005 California Building Energy Efficiency Standards, Part III*, July 3, 2002, p. 17-66. Presented at the July 18, 2002 workshop.

system efficiency. The default input parameters are presented in Appendix F. If the user specifies diagnostic testing to be performed during construction, the ACM shall request the user to enter the data described in Section 4.19, *Duct Efficiency* and shall report all required measurements and the features used to achieve higher HVAC distribution efficiencies in the *HERS Required Verification* listings. When the user chooses diagnostic testing, the diagnostic testing shall be performed as described in Appendix F. Diagnostic testing must be reported in the *HERS Required Verification* listings on the CF-1R and C-2R as described in Chapter 2.

Standard Design: The standard heating and cooling system for central systems is assumed to have air distribution ducts located in an attic space, 6% total tested duct leakage, non-~~ACCA Manual D~~ designed duct system, and a radiant barrier in climate zones where required by Package D. The Standard Design duct insulation is determined by the Package D specifications for the applicable climate zone. ~~R-4.2 duct insulation is assumed for the *Standard Design* building.~~ The *Standard Design* building is assumed to have the same number of stories as the *Proposed Design* for purposes of determining the duct efficiency. HVAC distribution system efficiencies must be calculated using the algorithms and equations in Appendix F of this manual for both the *Proposed Design* and the *Standard Design*. The *Standard Design* calculation must use the default values of that procedure. For non-central HVAC systems, the *Standard Design* shall have no ducts.

3.8 Infiltration/Ventilation

The intentional or unintentional replacement of conditioned indoor air by unconditioned outdoor air creates heat gains or heat losses for a conditioned building. This exchange of indoor and outdoor air occurs for all buildings to a greater or lesser extent. Mechanical ventilation gives a certain degree of control of the rate of this exchange and depending on the balancing of the ventilation may create building pressurization.

Proposed Design: As a default, ACMs shall not require the user to enter any values related to infiltration or mechanical ventilation for air quality and shall set the infiltration level to be the same as the standard design. ACMs shall allow a user to specify if they will be using diagnostic testing during building construction or if they wish to take infiltration reduction credit for an air-retarding wrap or reduced duct leakage. An air retarding wrap can qualify for a default reduction in Specific Leakage Area (SLA) of 0.50 without confirmation by diagnostic testing. The air retarding wrap must be tested and labeled by the manufacturer to comply with ASTM E1677-95, *Standard Specification for an Air Retarder (AR) Material or system for Low-Rise Framed Building Walls* and have a minimum perm rating of 10. The air-retarding wrap must be installed per the manufacturer's specifications that must be provided to comply with ASTM E1677-95. The default infiltration (no diagnostic testing and measurement of infiltration) credit for reduced duct leakage is also an SLA reduction of 0.50. Neither of these credits may be taken if the user chooses a diagnostic testing target for reduced infiltration. Either of these prescriptive infiltration reduction credits are special features and must be listed in the *Special Features and Modeling Assumptions* listings of the CF-1R and C-2R. The air retarder specifications listed above must also be reported in the *Special Features and Modeling Assumptions* listings when an air retarder is modeled by the ACM. If the user specifies they will be using diagnostic testing during construction, for either reduced infiltration or reduced infiltration with mechanical ventilation, the ACM must require the user to choose an input menu to enter a target value for measured $CFM50_H$ or the SLA corresponding to the target $CFM50_H$, and, if mechanical ventilation is to be used, the wattage and cfm of the ventilation supply and exhaust fans. Note that when the *Proposed Design* target value for reduced infiltration falls below a value corresponding to an SLA of 3.0, mechanical ventilation is required and this requirement must be reported as described in Chapter 2. Whenever mechanical ventilation is modeled (required or not), the volumetric capacity modeled must be at least 0.047 cfm/ft^2 of conditioned floor area. This minimum capacity is needed to provide adequate ventilation for indoor air quality. If the user attempts to model total mechanical volumetric capacity (balanced + unbalanced) less than 0.047 cfm/ft^2, then the ACM must indicate an input error and automatically block compliance output.

Tested infiltration below a value corresponding to an SLA of 1.5 is not allowed unless mechanical **supply** ventilation is installed adequate to maintain the residence at a pressure greater than -5 pascals relative to the outside average air pressure with other continuous ventilation fans operating. When the user chooses diagnostic testing, the diagnostic testing shall be performed using fan pressurization of the building in accordance with ASTM E 779-1987 (Reapproved 1992), *Standard Test Method for Determining Air Leakage Rate by Fan Pressurization* and the equipment used for this test must meet the instrumentation specifications found in Section 4.1 of Appendix F. The specifications for diagnostic testing and the target values specified above must be reported in the *HERS Required Verification* listings on the CF-1R and C-2R as described in Chapter 2.

Standard Design: The *Standard Design* does not use mechanical ventilation and assumes infiltration corresponding to a Specific Leakage Area (SLA) of 4.9 for ducted HVAC systems and an SLA of 3.8 for non-ducted HVAC systems.

Refer to Sections 4.17 and 4.17.1 for more detailed information.

3.9 Additions

Additions are treated as separate new buildings except for the determination of internal heat gains, which are specified in Section 4.5 for the purpose of determining a *Standard Design* for the addition. The modeling of additions or alterations must be reported in the *Special Features and Modeling Assumptions* listings, which must state that the building vintage and the input assumptions corresponding to this vintage must be verified prior to alteration to receive credit.

When an existing HVAC system is extended to serve an addition, the default assumptions for duct and HVAC distribution efficiency must be used for both the *Proposed Design* and the *Standard Design*. However, when a new, high efficiency HVAC distribution system is used to serve the addition or the addition and the existing building, that system may be modeled to receive energy credit subject to diagnostic testing and verification of proper installation by a HERS rater.

Proposed Design: The user must enter an indication that an addition is being modeled and the conditioned floor area of the addition for the *Proposed Design*. When an ACM has the capability of running an existing building plus an addition in a single pass, the addition and the existing building must be entered independently and reported independently. Special output must be created to clearly indicate existing building components separately from new components. Likewise altered existing components must have separate accounting and reporting. Existing building components must be reported exclusively in lowercase type and new or altered components exclusively in UPPERCASE type for single pass Addition with Existing Building runs or Alteration runs. ACMs that require two or more passes to model these situations do not require these restrictions on type case for existing and new (or altered) component reporting but these ACMs must clearly indicate which run corresponds to existing conditions and which run corresponds to the new or altered conditions and the *Special Features and Modeling Assumptions* listings for both runs must report that two output files, two CF-1Rs and two C-2Rs are required to be checked.

An existing building plus an addition may be modeled by means of two separate compliance runs:

The user or the ACM models the *Existing Building* and the *Addition plus the Altered Existing Building.* There will be two sets of energy use figures for each of these energy simulation runs, the predicted energy use of the modeled building (EU) and the predicted energy budget calculated based on the rules specified in this manual (EB).

Let

EU_e = the energy use of the existing building (*Proposed Design*).

EB_e = the energy budget for the existing building (*Standard Design*).

EU_{e+a} = the energy use of the altered existing building with the addition.

EB_{e+a} = the energy budget of the altered existing building with the addition.

and

A_e = the conditioned floor area of the existing building.

A_{e+a} = the conditioned floor area of the altered existing building with the addition.

$$F = \frac{A_e}{\left(A_{e+a}\right)} \qquad \text{Equation 3.4}$$

The altered existing building with the addition complies with the Standards when Equation 3.2 is satisfied:

$$EU_{e+a} \leq EB_{e+a} + F \times \left(EU_e - EB_e\right)$$ Equation 3.5

When no water heating is proposed for the addition, the ACM must report that no water heating energy is being calculated and the energy budgets cannot reflect the use of water heating energy. When a new water heater is replacing the existing water heater for the whole dwelling, the ACM must use the existing plus addition approach to compliance with the water heater modeled with the existing building. When the specifications of the existing water heater are unknown, the water heating budget is determined as if the dwelling were all new construction.

If the addition increases the number of water heaters in the dwelling then the addition *Standard Design* must be modeled with a non-circulating, gas-fired water heater with a volume which is the lessor of the *Proposed Design* volume or 50 gallons and an Energy Factor of 0.60. If the building does not have gas service, the ACM may allow the *Standard Design* water heater to be a non-circulating electric water heater with an Energy Factor of 0.98.

Standard Design: For additions, the *Standard Design* shall have a total glazing area equal to that allowed by Package D and the conditioned floor area of the addition just as for new buildings. For the *Standard Design* the glazing orientation, U-value, and SHGC of the fenestration shall be modeled in the same manner as a new building.

When additions are modeled with an existing building, the ACM must require the user to determine and enter the vintage of the existing building. The ACM shall then use the default assumptions specified in Table R3-7 for modeling the existing structure. If the ACM allows the user to enter higher U-values, higher F2 values, higher SHGCs, lower efficiencies, or lower energy factors than the vintage defaults from Table R3-7 for the existing building's *Proposed Design*, the ACM must report such values as special features on the *Special Features and Modeling Assumptions* listings.

Table R3-7 - Default Assumptions for Existing Buildings

		Default Assumptions for Year Built (Vintage)				
Conservation Measure		**Before 1978**	**1978 to 1983**	**1984 to 1991**	**1992 to 1998**	**1999 +**
INSULATION U-VALUE						
Roof		0.076	0.047	0.047	0.047	0.047
Wall		0.386	0.096	0.096	0.088	0.088
Raised Floor -CrawlSp		0.097	0.097	0.097	0.037	0.037
Raised Floor-No CrawlSp		0.239	0.239	0.239	0.097	0.097
Slab Edge	F2 =	0.76	0.76	0.76	0.76	0.76
Ducts		R-2.1	R-2.1	R-2.1	R-4.2	R-4.2
LEAKAGE						
Building (SLA)		4.9	4.9	4.9	4.9	4.9
Ducts		28%	28%	28%	28%	28%
FENESTRATION						
U-value		Use Table 1-D - Title 24, Part 6, Section 116 for all Vintages				
SHGC		Use Table 1-E - Title 24, Part 6, Section 116 for all Vintages				
Shading Dev.		Use Table R3-3 for all Vintages				
SPACE HEATING EFFICIENCY						
Gas Furnace (Central) AFUE		0.75	0.78	0.78	0.78	0.78
Heat Pump	HSPF	5.6	5.6	6.6	6.6	6.8
Electric Resistance HSPF		3.413	3.413	3.413	3.413	3.413
SPACE COOLING EFFIC.						
All Types,	SEER	8.0	8.0	8.9	9.7	9.7
WATER HEATING						
Energy Factor		0.525	0.525	0.525	0.525	0.58
Rated Input, MBH		28.0	28.0	28.0	28.0	28.0

4. Required Modeling Assumptions and Algorithms

Most of the modeling assumptions and algorithms about building operation and climate are either fixed or restricted when an ACM is used for compliance. All approved ACMs must include and automatically use all the appropriate fixed and restricted inputs and calculation methods with no special entry required by the user. Users may not override the fixed inputs when the ACM is used for compliance calculations, nor may they be allowed to go beyond the limitations of the restricted assumptions.

The fixed and restricted modeling assumptions apply to both the *Standard Design* run and to the *Proposed Design* run. The *standard* fixed and restricted modeling assumptions always apply to the *Standard Design* run and are the *default* for the *Proposed Design* run. In some cases, the CEC has approved *alternate* fixed and restricted modeling assumptions that may be used in the *Proposed Design* run. The alternate modeling assumptions may only be used when the *Proposed Design* run has a special building feature (e.g. zonal control) that is recognized as an approved Exceptional Method, and the ACM has been approved with this optional modeling capability. The modeling of such building features for compliance purposes must always be documented as entries in the *Special Features and Modeling Assumptions* listings on the Certificate of Compliance and on the Computer Method Summary.

The following subsections describe the fixed and restricted modeling assumptions or computer inputs and explain how they apply to both the *Standard Design* run and the *Proposed Design* run.

When this manual describes the algorithms and calculational methods used by the reference method, an ACM may use alternative algorithms to calculate the energy use of low-rise residential buildings provided that the algorithms are used consistently for the *Standard Design* and the *Proposed Design* and provided that the ACM passes the applicable tests described in Chapters 5 and 6 and provided that the appropriate input summaries and output information is correctly produced by the ACM. The reference methods of calculation are implemented in the CALRES computer program and used to generate the tests in Chapters 5 and 6.

However, certain algorithms and calculational procedures such as water heating and duct efficiency calculations must be modeled to produce intermediate results precisely and in detail. Typically the tests for these procedures will consist of random testing and result comparison of these intermediate results from a large number of possible tests and conditions.

4.1 Thermostats[14]

Standard Design & ***Proposed Design***: The *standard* thermostat settings are shown in the Table R 4-1 and Table R 4-2 below. These thermostat setpoints apply to the *Standard Design* run and are the default for the *Proposed Design* run.

[14] The justification for changes in this section appears in Eley Associates, *Residential Computer Modeling Draft – Status Report*, March 21, 2002. Presented at the April 2, 2002 workshop.

Table R4-1 - Thermostat Settings

	Cooling Mode	Heating Mode
Cooling Thermostat	78°F	78°F
Cooling Setup	83°F to 79°F	N/A
Heating Thermostat	60°F	68°F
Heating Setback	60°F	65~~0~~°F
Ventilation Setpoints	68°F or Off	77°F
~~Change-over Temperature~~	~~60°F~~	~~60°F~~

When the building is in the heating mode, the heating setpoints are set to the values in Table R 4-2, the cooling setpoint is set to a constant 78°F and the ventilation setpoint is set to a constant 77°F.

When the building is in the cooling mode, the heating setpoint is set to a constant 60°F, and the cooling and venting setpoints are set to the values in Table R 4-2.

~~It is assumed that the building has a constant cooling setpoint of 78°F. When the building is in a heating mode, the heating setpoint is 68°F with night setback to 60°F. The heating thermostat is set back from 11:00 pm until 7:00 am. During the summer or when the building is in a cooling mode, the heating setpoint is a constant 60°F.~~

~~The ventilation setpoint is 68°F when the building is in a cooling mode and 77°F when the building is in a heating mode.~~ The state of the building's conditioning mode is dependent upon the outdoor temperature averaged over hours 1 through 24 of day 8 through day 2 prior to the current day. The ACM shall calculate and update daily this 7-day running average of outdoor air temperature. When this average temperature is equal to or less than 60°F the building shall be set in a heating mode and all the thermostat setpoints for the heating mode shall apply. When the running average is greater than 60°F the building shall be set to be in a cooling mode and the cooling mode setpoints shall apply.

~~The standard heating and cooling setpoints are shown in Table 4-2 below for each hour of the day.~~

Table R4-2 - Standard Thermostat Set Points

Hour	Heating	Cooling	Venting	Hour	Heating	Cooling	Venting	Hour	Heating	Cooling	Venting
1	65	78	Off	9	68	83	68	17	68	79	68
2	65	78	Off	10	68	83	68	18	68	78	68
3	65	78	Off	11	68	83	68	19	68	78	68
4	65	78	Off	12	68	83	68	20	68	78	68
5	65	78	Off	13	68	83	68	21	68	78	68
6	65	78	68	14	68	82	68	22	68	78	68
7	65	78	68	15	68	81	68	23	68	78	68
8	68	83	68	16	68	80	68	24	65	78	Off

~~Table 4-2 - Standard Thermostat Set Points~~

~~Hour~~	~~Heating~~	~~Cooling~~	~~Hour~~	~~Heating~~	~~Cooling~~	~~Hour~~	~~Heating~~	~~Cooling~~
~~1~~	~~60~~	~~78~~	~~9~~	~~68~~	~~78~~	~~17~~	~~68~~	~~78~~
~~2~~	~~60~~	~~78~~	~~10~~	~~68~~	~~78~~	~~18~~	~~68~~	~~78~~
~~3~~	~~60~~	~~78~~	~~11~~	~~68~~	~~78~~	~~19~~	~~68~~	~~78~~
~~4~~	~~60~~	~~78~~	~~12~~	~~68~~	~~78~~	~~20~~	~~68~~	~~78~~
~~5~~	~~60~~	~~78~~	~~13~~	~~68~~	~~78~~	~~21~~	~~68~~	~~78~~
~~6~~	~~60~~	~~78~~	~~14~~	~~68~~	~~78~~	~~22~~	~~68~~	~~78~~
~~7~~	~~60~~	~~78~~	~~15~~	~~68~~	~~78~~	~~23~~	~~68~~	~~78~~
~~8~~	~~68~~	~~78~~	~~16~~	~~68~~	~~78~~	~~24~~	~~60~~	~~78~~

Proposed Design: An optional capability, described in Section 6.2, allows alternative thermostat schedules to be used for the *Proposed Design* run when the HVAC system meets the requirements for zonal control. With zonal control, the building is divided into sleeping and living areas and a separate schedule is used for each area. If the user selects this option the ACM shall select the appropriate alternative schedules based on the user's designations for sleeping and living zones and shall automatically report the use of this optional capability in the *Special Features and Modeling Assumptions* listings in the required standard reports.

Certain types of heating and/or cooling equipment are exempt from the mandatory requirement for setback thermostats, including wall furnaces and through-the-wall heat pumps. If setback thermostats are not installed, then the ACM shall model the *Proposed Design* with the standard thermostat schedule, except that the heating mode setback setpoint shall be 66°F instead of ~~60~~65°F. In cases where setback thermostats are not mandatory but nonetheless are installed by the builder, the ACM shall model the *Proposed Design* using the standard heating setback setpoint of ~~60~~65°F. The *Standard Design* always assumes the setback schedule shown in Table R 4-2.

4.2 R-Value/U-Value Determinations and Calculations[15]

According to the Standards, the R-value of a material is "the [thermal] resistance of a material or building component to the passage of heat in (hr x ft^2 x ºF)/Btu."

The R-value indicates how well a material prevents heat from flowing through it. R-19 insulation, for example, is only half as effective at slowing heat transfer as R-38 insulation.

Overall thermal resistances (overall R-values) and overall thermal transmittance values (overall U-value) shall be calculated using algorithms and methods consistent with the algorithms and methods in the 1997 ASHRAE Handbook of Fundamentals, Chapters 22, 23 and 24. For construction assemblies or portions of construction assemblies that consist of two or more plane parallel layers of materials in series (such as exterior siding, insulation and interior gypsum board), the thermal resistance of the assembly is equal to the sum of the individual thermal resistances. When layers are penetrated or interrupted by wood framing or other framing elements that do not readily conduct heat, the parallel path method shall be used to calculate the R-value and U-value of the construction assembly. Standard wood frame walls with studs 16" on center shall be assumed to have 25% framing for parallel path calculations. When metal framing is used or construction layers are penetrated by other significant amounts of highly heat conductive materials such as metals, the zonal calculation method, modified zonal calculation method, finite element or finite difference methods, or the Commission's EZ-frame computer program must be used to determine overall R-value and overall U-value.

Most typical constructions can be calculated using the parallel path method and documented using the residential compliance Form 3R.

The U-value is the inverse of the total R-value:

15 Changes in this section are based on extensive public comments and review of Eley Associates, "Construction Quality -- Walls," *Measure Analysis and Life-Cycle Cost: 2005 California Building Energy Efficiency Standards, Part I*, April 11, 2002, p. 24-30. Presented at the April 23, 2002 workshop.

$$U = 1/RTotal \qquad \text{Equation 4.1}$$

The U-value is the heat transfer coefficient expressed in Btu/ft^2-hr-^{o}F, the rate at which heat flows through an assembly or material.

The total R-value shall be entered, displayed, and calculated to at least three significant figures, or, alternatively to two decimal places, and the total U-value to two significant figures or three decimal places whichever is more precise.

4.2.1 Default R-values/U-values in Appendix E

Appendix E contains pre-calculated Form 3Rs for a number of standard assemblies. The Total R-values and U-values from these assemblies must be used in compliance calculations unless a Form 3R is completed for the actual proposed assembly, or unless the compliance approach only uses the insulation level alone. Table E-7 in Appendix E summarizes these default U-values.

Appendix E also includes Form 3Rs for assemblies that meet the default U-values with a combination of batt and rigid insulation, rather than only batt insulation (including metal frame assemblies). In addition, it contains R-values and other information on a variety of masonry wall assemblies.

To determine if an assembly meets the minimum insulation levels required by the mandatory measures or the prescriptive packages, obtain the U-value of the proposed assembly or complete a Form 3R and see if the proposed U-value is less than or equal to the standard U-value for that assembly type and insulation level as listed in Table 3-1 in Chapter 3 and Table E-2 in Appendix E. Compare the proposed U-value to the U-values listed for framing spacing of 16" o.c. for walls and 24".o.c. for roofs/ ceilings.

4.2.2 Insulation Installation Quality

Standard Design: The Standard Design shall have standard Envelope Construction Quality.

Proposed Design: Energy credit for improved Envelope Construction Quality may be used with approved alternative calculation methods (ACMs). Approved ACMs must be able to model standard and improved Envelope Construction Quality.

ACMs model wall construction quality year round by multiplying the U-factor for walls by 1.19 for buildings with standard Envelope Construction Quality and by 1.05 for cases with improved Envelope Construction Quality.

For the heating season, add 0.02 times the area to the UA of each ceiling surface with Standard Envelope Construction Quality and 0.01 times the area to the UA of each ceiling surface if credit is claimed for improved Envelope Construction Quality.

For the cooling season, add 0.005 times the area to the UA of each ceiling assembly with Standard Envelope Construction Quality and 0.002 times the area to the UA of each ceiling surface if credit is claimed for improved Envelope Construction Quality.

The use of improved Envelope Construction Quality shall be listed in the Special Features and Modeling Assumptions listings of the CF-1R and C-2R and described in detail in the ACM Compliance Supplement. Installers claiming credit shall certify insulation quality and raters shall verify it using the procedures of Appendix Q.

4.3 Basement Modeling - Basement Walls and Floors

Below grade walls shall have no exterior absorptivity (no radiant gain from sunlight). Below grade walls are modeled with three exterior conditions depending on whether the depth is shallow, medium, or deep.

4.3.1 Shallow Depth Walls

The first two feet (inclusive) of the below grade wall uses the average air temperature for hours 1 through 24 of the 7 days beginning 8 days prior to the current day (days -8 through -2). In addition, a thermal resistance with an R-value of 1.57 (hr.ft^2.^{o}F/Btu) is added between this average temperature and the outside of the below grade wall.

4.3.2 Medium Depth Walls

The basement walls from more than 2 feet below grade through 6 feet below grade have an exterior temperature that is the average of hours 1 though 24 of the 7 days of outdoor temperature from the period starting 68 days prior to the current day being simulated through 62 days prior to the first hour of the current day being simulated. In addition, a thermal resistance with an R-value of 7.28 (hr.ft2.^{o}F/Btu) is added between this lagged average temperature and the outside of the below grade wall.

4.3.3 Deep Walls and Floors

Walls more than 6 feet below grade and basement floors have an exterior temperature that is typical of deep ground temperatures. These temperatures are given in Table R 4-3 below for each of the sixteen climate zones. In addition, a thermal resistance with an R-value of 13.7 (hr.ft2.^{o}F/Btu) is added between this average temperature and the outside of the below grade wall. For basement floors this added R-value is 17.6 hr.ft2.^{o}F/Btu.

Table R4-4 Temperatures for Deep Walls and Floors by Climate Zone

Climate Zone	Deep Ground Temperature
1	49.1
2	64.5
3	62.8
4	61.4
5	56.8
6	64.1
7	61.6
8	63.9
9	66.4
10	68.9
11	69.5
12	67.8
13	67.6
14	68.6
15	74.6
16	54.1

4.4 Shading Calculations

4.4.1 Interior Shading and Exterior Sunscreen Operation

Standard Design & ***Proposed Design***: The standard assumptions for operation of interior shading devices and sunscreens shall apply to both the *Standard Design* run and the *Proposed Design* run.

Draperies are assumed to be closed only for hours when the air conditioner operates. To approximate this affect during transitions between periods of operation and non-operation, ACMs may assume that the internal device remains closed for the hour following the period of air conditioner operation. As soon as that hour passes, the internal shading device shall be opened. The internal device shall be either totally open or totally closed for any given hour.

External sunscreens are assumed to be in place all year, whether the building is in a heating or cooling mode.

The shading effects of overhangs, side fins and other fixed shading devices are determined hourly based on the altitude and azimuth of the sun for that hour, the orientation of the fenestration, and the relative geometry of the fenestration and the fixed shading devices.

4.4.2 Solar Heat Gain Coefficients

Solar Heat Gain Coefficients shall be determined according to Chapter 3 of this manual. ACMs use two values for setting the Solar Heat Gain Coefficient of shading devices: "$SHGC_{open}$ " and "$SHGC_{closed}$." "$SHGC_{open}$ " applies when the air conditioner is not in operation (off) and "$SHGC_{closed}$ " applies when the air conditioner is in operation. The ACM user shall not be allowed to enter values for $SHGC_{open}$ and $SHGC_{closed}$. These values must be automatically calculated from the specification of the SHGC for the fenestration ($SHGC_{fen}$), the exterior shade and the interior shade as described below. ACMs shall forbid users from direct entry of SHGCs for interior and exterior shading devices. The ACM must automatically determine these values from the user's choices of exterior shading devices and from the assumption that vertical glazing has a drapery and non-vertical (skylight) glazing has no interior shading device.

There are a limited set of shading devices with fixed prescribed characteristics that are modeled in the performance approach. These devices and their associated fixed Solar Heat Gain Coefficients are listed in Table R 3-2 and Table R 3-3.

The formula for combining Solar Heat Gain Coefficients is:

$$SHGC_{comb} = \left[\left(0.2875 \times SHGC_{\max}\right) + 0.75\right] \times SHGC_{\min} \qquad \text{Equation 4.2}$$

Where

$SHGC_{comb}$ = the combined solar heat gain coefficient for a fenestration component and an attachment in series.

$SHGC_{max}$ = the larger of $SHGC_{fen}$ and $SHGC_{dev}$

$SHGC_{min}$ = the smaller of $SHGC_{fen}$ and $SHGC_{dev}$

Where

$SHGC_{fen}$ = the Solar Heat Gain Coefficient of the fenestration which includes the window glazing, transparent films and coatings, and the window framing, dividers and muntins,

$SHGC_{dev}$ = the Solar Heat Gain Coefficient of the interior or exterior shading device when used with a metal-framed, single pane window.

For $SHGC_{closed}$, the combination SHGC, $SHGC_{fen+int}$, (the combined SHGC for the fenestration and the interior device) is calculated first and then the combination $SHGC_{fen+int+ext}$ is calculated to determine the overall $SHGC_{closed}$. $SHGC_{open}$ is determined from the combination of $SHGC_{fen}$ and $SHGC_{ext}$.

The combination $SHGC_{fen+int}$ is calculated as above for the *Standard Design* when the Package D specification for SHGC is No Requirement with SHGC = NR (No Requirement) set to a default SHGC of 0.70, which is typical of a double pane, metal-framed window.

$SHGC_{fen+int}$ = [($SHGC_{fen}$ x 0.2875) + 0.75] x $SHGC_{drap}$

or

$SHGC_{fen+int}$ = [(0.70 x 0.2875)+0.75] x 0.68 = [0.95125] x 0.68 = 0.64685

With the effects of the exterior shade,

$SHGC_{fen+ext}$ = [($SHGC_{ext}$ x 0.2875) + 0.75] x $SHGC_{fen+int}$

or

$SHGC_{closed} = SHGC_{fen+int+ext}$ = [(0.76 x 0.2875)+0.75] x 0.64685

= [0.9685] x 0.64685 = 0.626 and

$SHGC_{open} = SHGC_{fen+ext}$ = [(0.76 x 0.2875)+0.75] x 0.70

= [0.9685] x 0.70 = 0.678

4.5 Internal Gains

Standard Design & ***Proposed Design***: Internal gain from lights, appliances, people and other sources shall be set to 20,000 Btu/day for each dwelling unit plus 15 Btu/day for each square foot of conditioned floor area (CFA) as shown in Equation 4.3.

$$IntGain_{total} = (20{,}000xN) + (15x\sum_{i=1}^{N} CFA_i) \qquad \text{Equation 4.3}$$

Where

N= number of dwelling units (NumDwellUnits)

CFA_i=Conditioned Floor Area of i^{th} dwelling unit

For addition-alone compliance (single-zone), the gains are apportioned according to the fractional conditioned floor area, referred to as the Fractional Dwelling Unit (FDU). For zone j, the internal gain is determined by Equation 4.4:

$$IntGainZone_j = IntGain_{tot}\ x\ FDU_j \qquad \text{Equation 4.4}$$

Where

FDU_j = Fractional Dwelling Unit of j^{th} zone, calculated from Equation 4.5

$$FDU_j = \frac{CFA_j}{\sum_{i=1}^{N} CFA_i} \qquad \text{Equation 4.5}$$

When zonal control is a feature of the *Proposed Design* for a single dwelling unit, the total internal gain is split between the living areas and the sleeping areas as described in Section 6.2.3, pg. 6-4

Building additions may be modeled in conjunction with the existing dwelling or modeled separately (see Sections 6.7.1 and 6.7.2). When modeled together the number of dwelling units for the proposed dwelling ($NDU_{proposed}$) remains equal to the number of dwelling units for the existing structure ($NDU_{existing}$), while the conditioned floor area ($CFA_{proposed}$) is increased to include the contribution of the addition ($CFA_{addition}$). When modeled separately, the internal gain of the addition ($IntGain_{addition}$)is based on the value of the addition's fractional dwelling unit ($FDU_{addition}$), as expressed in Equations 4.6 and 4.7.

Modeling additions is an optional capability described in Section 6.7, Page 6-17.

$$IntGain_{addition} = IntGain_{total}\ x\ FDU_{addition} \qquad \text{Equation 4.6}$$

where

$$FDU_{addtion} = \frac{CFA_{addition}}{CFA_{existing} + CFA_{addition}}$$ Equation 4.7

4.6 Internal Gain Schedules

Standard Design & ***Proposed Design***: For hourly computer models, the standard internal gain schedule shown in Table R 4-4 applies. “Hour one” is between midnight and 1:00 am. This schedule shall always be used for the *Standard Design* run. It is the default for the *Proposed Design* run and shall be used unless the *Proposed Design* has zonal control. For zonal control assumptions, see Chapter 6, Section 6.2.

Table R4-5 - Standard Internal Gain Schedule

Hour	Percent	Hour	Percent	Hour	Percent
1	2.4	9	5.6	17	5.7
2	2.2	10	6.0	18	6.4
3	2.1	11	5.9	19	6.4
4	2.1	12	4.6	20	5.2
5	2.1	13	4.5	21	5.0
6	2.6	14	3.0	22	5.5
7	3.8	15	2.8	23	4.4
8	5.9	16	3.1	24	2.7

Daily internal gain shall be modified each month according to the set of multipliers shown in Table 4-5. These multipliers are derived from the number of daylight hours each month.

Table R4-6 - Seasonal Internal Gain Multipliers

Month	Multiplier	Month	Multiplier	Month	Multiplier
Jan	1.19	May	0.84	Sep	0.98
Feb	1.11	Jun	0.80	Oct	1.07
Mar	1.02	Jul	0.82	Nov	1.16
Apr	0.93	Aug	0.88	Dec	1.21

4.7 Thermal Mass

Standard Design & ***Proposed Design***: Thermal mass is modeled in both the *Proposed Design* and the *Standard Design*. The modeled mass includes the basic thermal mass such as framing, furniture, 0.5” sheetrock, and household appliances as “light” mass elements and specific “heavy” mass elements such as concrete slab floors. This modeled thermal mass has the ability to store heat and thus damp temperature fluctuations in the conditioned space. The *Proposed Design* and the *Standard Design* must have the same “light” mass elements and for most dwellings the Standard and *Proposed Design*s will also have and model the same “heavy” mass elements.

ACMs must assume that both the *Proposed Design* and *Standard Design* building have a certain amount of minimum “heavy” thermal mass as a function of the conditioned area of slab floor and conditioned nonslab floor. Unless the *Proposed Design* has thermal mass that exceeds a thermal mass minimum threshold, the modeled thermal mass for both the *Proposed Design* and the *Standard Design* is 20% of the *Proposed Design*'s conditioned slab floor area as exposed slab, 80% of the conditioned slab floor area as rug-covered slab, and 5% of the *Proposed Design*’s conditioned nonslab floor area as exposed 2 inch thick concrete.

The modeled exposed slab floor has the following default characteristics: a thickness of 3.5 inches, a volumetric heat capacity of 28 Btu/ft^3-°F, a conductivity of 0.98 Btu-in/hr-ft^2-°F, a surface conductance of 1.3 Btu/hr-ft^2-°F (no thermal resistance on the surface). The remaining 80% of the conditioned slab floor shall be modeled as covered thermal mass with the same characteristics as the exposed mass, but with the addition of a surface R-value of 2.0 (hr-ft^2-°F)/Btu typical of a carpet and pad.

Conditioned nonslab floor area shall be modeled with 5% of the nonslab floor area as exposed thermal mass. This thermal mass is modeled in the *Standard Design* with a thickness of 2.0 inches, a volumetric heat capacity of 28 Btu/ft^3-°F, a conductivity of 0.98 Btu-in/hr-ft^2-°F, a surface conductance of 1.3 Btu/hr-ft^2-°F (no added thermal resistance on the surface). The ACM must also model it this way in the ***Proposed Design*** unless the ***Proposed Design*** exceeds the thermal mass threshold. The ACM may also require that the user specify a "high mass" or "passive solar" option before allowing the entry of special mass elements and the modeling of thermal mass when the total thermal mass exceeds the high mass threshold.

Proposed Design: The *Proposed Design* may model additional thermal mass when the user selects the ACM's "high mass" building input option by modeling thermal mass in excess of the assumed thermal mass for the *Standard Design* when the equivalent design thermal mass for the *Proposed Design* reaches or exceeds a specific mass threshold. This threshold is determined by the amount of thermal mass equivalent to 30% of the conditioned slab floor area as exposed 3.5" thick concrete slab, 70% of the conditioned slab floor area as rug-covered 3.5" thick concrete slab and 15% of the conditioned raised floor area as 2 inch thick exposed concrete with the same specifications as those given above. To determine the threshold, this mass is converted to a standard Interior Mass Capacity using the Unit Interior Mass Capacity (UIMC) method described in Appendix I and compared to the design mass to determine if the mass threshold is exceeded.

4.7.1 Perimeters of Slab Floors and Carpeted Slabs

Standard Design & ***Proposed Design***: For *Standard and Proposed Designs* all ACMs must use slab edge F2 values assuming that 20% of the slab floor perimeter is exposed to the conditioned air and 80% of the slab floor perimeter is carpeted or covered with an R-2 insulating layer between the slab and the conditioned air.

The monthly ground temperatures for each month as shown in Table 4-6 shall be used as the exterior temperature when calculating slab edge heat exchange.[16]

[16] The justification for changes in this section appears in Eley Associates, *Residential Computer Modeling Draft – Status Report*, March 21, 2002. Presented at the April 2, 2002 workshop.

Table R4-7 - Monthly Ground Temperatures

	Month											
Climate Zone	1	2	3	4	5	6	7	8	9	10	11	12
1	52.2	51.5	51.4	51.8	53.1	54.5	55.6	56.4	56.4	55.8	54.7	53.4
2	53.3	51.5	51.4	52.2	55.6	58.9	61.8	63.6	63.8	62.3	59.5	56.3
3	55.1	54.1	54.0	54.5	56.5	58.5	60.3	61.4	61.5	60.6	58.9	56.9
4	55.5	54.0	53.9	54.6	57.5	60.3	62.8	64.3	64.5	63.2	60.8	58.0
5	55.7	54.8	54.7	55.2	56.9	58.7	60.2	61.1	61.2	60.4	59.0	57.3
6	59.1	58.1	58.0	58.5	60.4	62.4	64.0	65.1	65.2	64.3	62.7	60.8
7	60.1	59.1	59.0	59.5	61.5	63.4	65.2	66.2	66.3	65.5	63.8	61.9
8	60.0	58.8	58.7	59.2	61.6	63.9	66.0	67.3	67.4	66.3	64.3	62.1
9	60.5	59.1	59.0	59.7	62.2	64.8	67.1	68.5	68.6	67.5	65.3	62.8
10	59.4	57.6	57.4	58.3	61.8	65.2	68.2	70.1	70.2	68.7	65.8	62.4
11	54.9	52.4	52.2	53.4	58.2	63.0	67.2	69.8	70.0	67.9	63.8	59.2
12	54.6	52.5	52.3	53.3	57.3	61.3	64.8	67.0	67.2	65.4	62.0	58.1
13	57.5	54.7	54.5	55.8	61.0	66.2	70.6	73.5	73.7	71.4	67.0	62.0
14	54.2	51.2	51.0	52.4	58.2	63.9	68.8	72.0	72.2	69.7	64.8	59.3
15	66.8	64.0	63.8	65.1	70.4	75.8	80.4	83.3	83.6	81.2	76.7	71.5
16	44.4	41.8	41.6	42.8	47.7	52.6	56.8	59.5	59.7	57.5	53.4	48.7

Standard Design: The slab perimeter shall be assumed to have an F2 value based on perimeter insulation as specified for Alternative Component Package D in Section 151 of the building efficiency standards. The Standard Design also assumes that no unconditioned spaces are attached to the conditioned space (in particular that the garage is detached), hence the total slab perimeter length is either insulated or uninsulated per the requirements of Alternative Component Package D. Hence, for the *Standard Design,* the slab edge heat loss factor, F2, is 0.76 for all climate zones except Climate Zone 16 where F2 is 0.51.

Proposed Design: Slab perimeter insulation shall be modeled using an F2 factor for the insulation to be installed and the perimeter length that is to be insulated. The slab perimeter length adjacent to unconditioned spaces such as a garage may be modeled as an R-7 insulated perimeter with an F2 factor of 0.51.

4.8 Solar Gain Targeting

Standard Design & ***Proposed Design***: Solar gains from windows or skylights shall not be targeted to mass elements within the conditioned space of the building. In the reference program, CALRES, all solar gain is targeted to the air or a combined air-and lightweight, high surface area mass node within the building. This modeling assumption is used in both the *Standard Design* run and the *Proposed Design* run, except for sunspaces where the user has flexibility in targeting solar gains subject to certain constraints. Sunspace modeling is an optional capability discussed in Section 6.3.

For compliance purposes, when glazing surfaces enclose unconditioned spaces, such as sunspaces, the user is allowed to target all but 25% of the solar gains from these surfaces to mass elements located within the unconditioned space. Unassigned solar gain is targeted to the air or the combined air/lightweight mass or to high surface area lightweight mass in the unconditioned space. At least 25% of the solar gain from any sunspace fenestration surface must be targeted to high surface area lightweight mass and/or the air. At most 60% of the solar gain may be targeted to the slab floor of a sunspace, especially in the summer. For compliance purposes, an ACM must automatically enforce these limits and inform the user of any attempt to exceed these limits.

4.9 Building Heat Capacity

Standard Design & ***Proposed Design***: The heat capacity associated with conventional framed construction includes 1/2 inch gypsum board, wall framing and building contents. The building heat capacity is assumed to be fixed at 3.5 Btu/°F per square foot of conditioned floor area. Other values may be used for unconditioned zones (see Chapter 6).

The assumed value shall apply to the *Standard Design* and shall be the default for the *Proposed Design*.

Proposed Design: The value may be adjusted in the *Proposed Design* run for a user-designated high mass design for special building features such as extra thick gypsum board or heavy mass elements. For such calculations, the surface area of gypsum board shall be assumed to be four times the conditioned floor area. The compliance supplement shall contain recommendations for modifying the building heat capacity, when applicable, and the ACM shall identify the variation in building heat capacity as a special feature of the building. This shall be noted in the "*Special Features and Modeling Assumptions*" listings of the standard reports.

4.10 Standard Weather Data

Standard Design & ***Proposed Design***: All ACMs must use standard weather data for all compliance runs. The standard weather data may be condensed, statistically summarized, or otherwise reduced. However, the basis must be the official Commission's hourly weather data.

The same weather data and weather data format must be used for both the *Standard Design* run and the *Proposed Design* run.

The official hourly weather data for energy compliance is available from the Commission on 1.44 megabyte, 3.5 inch floppy diskettes (IBM-PC format). There are 16 climate zones with a complete year of 8760 hourly weather records. Each climate zone is represented by a particular city. More detail on the weather formats is given in the description package mailed with the weather tapes. The weather data may be obtained by mailing a written request for the weather data, a self-addressed diskette mailer, and three IBM-formatted 1.44 Megabyte diskettes to: RESACM Weather Data, Residential Office, California Energy Commission, 1516 Ninth Street MS#25, Sacramento, California 95814-5512.

4.11 Ground Reflectivity

Standard Design & Proposed Design: ACMs shall assume that the ground surrounding residential buildings has a reflectivity of 20 percent in both summer and winter. This applies to both the *Standard Design* run and *Proposed Design* run.

4.12 Natural Ventilation

The natural ventilation model is derived from the 1997 *ASHRAE Handbook of Fundamentals*. The model considers both wind effects and stack effects.

- Wind effects include wind speed, prevailing direction and local obstructions, such as nearby buildings or hills.
- Stack effects include the temperature difference between indoor air and outdoor air and the difference in elevation between the air inlet and the outlet.

For compliance purposes, the air outlet is always assumed to be 180 degrees or on the opposite side of the building from the air inlet and the inlet and outlet areas are assumed to be equal. The default inlet area (= outlet area) is five percent of the total window area.

4.12.1 Effective Ventilation Area (EVA)

Both wind and stack driven ventilation depends linearly on the effective ventilation area (EVA). The EVA is a function of the area of the air inlet and the area of the air outlet. For compliance purposes, the default area of air inlet and outlet are both equal to five per cent (half of the total default standard window opening area) of the total window area. For compliance purposes a different window opening areas may be determined from the areas of different window opening types - fixed, sliders, and hinged windows. For research (as opposed to compliance) purposes, inputs for ACMs may enter separate values for inlet and outlet areas. For compliance purposes, the air inlet and the air outlet are each equal to one-half of the *Free Ventilation Area* described in Section 4.13 below.

When the inlet area and outlet area are equal, the EVA is the same, i.e. equal to the inlet area or the outlet area. Hence for compliance purposes the EVA is equal to one-half of the *Free Ventilation Area.*

4.12.2 Stack Driven Ventilation

Stack driven ventilation results when there is an elevation difference between the inlet and the outlet, and when there is a temperature difference between indoor and outdoor conditions.

$$CFM_S = 9.4 \times EVA \times EFF_S \times \sqrt{H \times \Delta T} \qquad \text{Equation 4.8}$$

Where:

CFM_S = Air flow due to stack effects, cfm.

9.4 = Constant from ASHRAE.

EVA = Effective ventilation area as discussed above, sf.

EFF_S = Stack effectiveness.

H = Center-to-center height difference between the air inlet and outlet.

ΔT = Indoor to outdoor temperature difference, °F.

For compliance purposes the stack effectiveness shall be set at 1.0. The ACM user shall not be permitted to alter this value.

H is the *ventilation height difference.* See Section 4.14 for details.

4.12.3 Wind Driven Ventilation

The general equation for wind driven ventilation is shown below. This equation works in either a direction dependent implementation or a direction independent implementation, as explained later in the text.

$$CFM_w = EVA \times 88 \times MPH \times WF \times EFF_o \times EFF_d \qquad \text{Equation 4.9}$$

Where:

CFM_W = Ventilation due to wind, cfm.

EVA = Effective vent area as discussed above, sf.

88 = A constant that converts wind speed in mph to wind speed in feet per minute.

MPH = Wind speed from the weather tape, mph.

WF = A multiplier that reduces local wind speed due to obstructions such as adjacent buildings.

EFF_O = Effectiveness of opening used to adjust for the location of the opening in the building, e.g. crawl space vents.

EFF_d = Effectiveness that is related to the direction of the wind relative to the inlet surface for each hour.

WF is the *wind correction factor*; this input is fixed at 0.25 for compliance calculations.

The effectiveness of the ventilation opening, EFF_o, is used to account for insect screens and/or other devices that may reduce the effectiveness of the ventilation opening. This input is also used to account for the location of ventilation area, e.g. the exceptional method for two-zone crawl space modeling provides for an alternative input for EFF_o. This input is fixed at 1.0 for compliance calculations other than crawlspace modeling.

ASHRAE recommends that the effectiveness of the opening, EFF_d, be set to between 0.50 and 0.60 when the wind direction is perpendicular or normal to the inlet and outlet. A value of 0.25 to 0.35 is recommended for diagonal winds. When the wind direction is parallel to the surface of the inlet and outlet, EFF_d should be zero.

For compliance calculations, the orientation of the inlet and outlet is not considered. ACMs shall assume that the wind angle of incidence at 45 degrees on all windows and only the wind speed dependence is maintained. In this case, the product of EFF_o and EFF_d is equal to 0.28 regardless of the direction of the wind.

4.12.4 Combined Wind and Stack Effects

Stack effects and wind effects are calculated separately and added by quadrature, as shown below. This algorithm always adds the absolute value of the forces; that is, wind ventilation never cancels stack ventilation even though in reality this can happen.

$$CFM_t = \sqrt{CFM_w^2 + CFM_s^2} \qquad \text{Equation 4.10}$$

Where:

CFM_t = Total ventilation rate from both stack and wind effects, cfm.

CFM_w = Ventilation rate from wind effects, cfm.

CFM_s = Ventilation rate from stack effects, cfm.

4.12.5 Determination of Natural Ventilation for Cooling

The value of CFM_t described in Equation 4.10 above gives the maximum potential ventilation when the windows are open. Natural ventilation is available during cooling mode when Ventilation is shown as On in Table 4.2. The amount of natural ventilation used by ACMs for natural cooling is the lessor of this maximum potential amount available and the amount needed to drive the interior zone temperature down to the natural cooling setpoint temperature when natural cooling is needed and available. When natural cooling is not needed or is unavailable no natural ventilation is used. ACMs shall assume that natural cooling is needed when the building is in “cooling mode” and when the outside temperature is below the estimated zone temperature and the estimated zone temperature is above the natural cooling setpoint temperature. Only the amount of ventilation required to reduce the zone temperature down to the natural ventilation setpoint temperature is used and the natural ventilation setpoint temperature must be constrained by the ACM to be greater than the heating setpoint temperature.

4.13 Free Ventilation Area

Free ventilation area is the adjusted area taking into account bug screens, window framing and dividers, and other factors.

Standard Design: The *Standard Design* value for free ventilation area is 10% of the fenestration area (rough frame opening). This value is also used for the window Opening Type *Slider*. The approved ACM compliance manual shall note that fenestration-opening type *Slider* also may be selected by the user or automatically used by the ACM as a default or "*Standard*" opening type. This is based upon the assumption that approximately 40% of the rough frame opening is available for ventilation. Half of this area is considered an air inlet and half an air outlet. This value shall always be used for the *Standard Design* run. It is also the default for the *Proposed Design* run.

Proposed Design: Other values may be used in the *Proposed Design* run only when special windows are installed, high mass is installed, and the "high mass" input option is selected [or the ACM determines that *Proposed Design's* thermal mass exceeds the mass threshold]. The free ventilation area is assumed to be 20% of the fenestration area for hinged type windows such as casements, awnings, hoppers, patio doors and French doors that are capable of a maximum ventilation area of approximately 80% of the rough frame opening. If the ACM user increases the ventilation area for hinged type windows, the ACM must also consider the possible effect of fixed glazing in the building which has no free ventilation area (window opening type *Fixed*). The ACM user may account for additional free ventilation area by entering the total area for sliding windows, the total area for hinged windows, and the total area of fixed windows in the "high mass" menu of the ACM. The ACM must verify that the total area entered for these three types is the same as the total area of windows calculated elsewhere or the ACM may determine the area of fixed windows by subtracting the slider window area and the hinged window area from the total window area if it is less than the total window and skylight area. If the total window and skylight area is less than the area specified for sliding windows and hinged windows the ACM must reduce the area of hinged windows by the difference. The total ventilation area is calculated from the areas of the three possible fenestration opening types, as shown below:

$$\mathrm{Vent}_{\mathrm{Area}} = (\mathrm{Area}_{\mathrm{Slider}} \times 0.1) + (\mathrm{Area}_{\mathrm{Hinged}} \times 0.2) + (\mathrm{Area}_{\mathrm{Fixed}} \times 0.0) \qquad \text{Equation 4.11}$$

The ACM's ability to accept a customized ventilation area is an optional capability. When this optional capability is used, the fact that the user entered a customized free ventilation area and the total areas of each of these three fenestration opening types must be reported in the *Special Features and Modeling Assumptions* listings on the CF-1R and C-2R. Note that the maximum free ventilation area that may be modeled by any ACM for compliance purposes is 20% of the total area of windows and skylights assuming that all windows and skylights are hinged.

4.14 Ventilation Height Difference

Standard Design: The *Standard Design* modeling assumptions for the elevation difference between the inlet and the outlet is two feet for one story buildings and eight feet for two or more stories.

Proposed Design: For the *Proposed Design* run, the assumption is the same as the *Standard Design* except that greater height differences may be used with special ventilation features such as high, operable clerestory windows. In this case the height difference is the height between the average center height of the lower operable windows and the average center height of the upper operable windows. Such features must be fully documented on the building plans and noted on the ACM standard reports in the *Special Features and Modeling Assumptions* listings as a condition that requires special verification.

4.15 Wind Speed and Direction

Standard Design & ***Proposed Design***: Wind speed affects the infiltration rate and the natural ventilation rate. The infiltration and ventilation rate in the reference method accounts for local site obstructions. For infiltration in the reference method this is done by using Shielding Class 4 coefficients in the Sherman-Grimsrud equation (Section 4.17.1, Equation 4.17) to determine the stack and wind driven infiltration and ventilation. This Shielding Class determination was made on the basis of the description of the Shielding Classes given in the 1997 ASHRAE Handbook of Fundamentals, Table 7, Page 25.22. For Shielding Class 4 the description reads:

Heavy shielding; obstructions around most of the perimeter, buildings or trees within 30 feet in most directions; typical suburban shielding.

For natural ventilation in the reference method, the wind speed used in calculations is adjusted for differences between the measured wind speed height and the inlet opening height and local obstructions by using a wind factor (WF in Equation 4.9) of 0.25.

4.16 Solar Gain[17]

Solar gain through glazing shall be calculated using the methods documented in the *Algorithms and Assumptions Report, 1988*. This method is modified, however, for the standards effective after 1998. Solar gain through windows is reduced to 75~~67.5~~ percent of the full solar gain and a new algorithm is used to calculate the transmitted solar gain as a function of the angle of incidence on the glazing. The 0.~~6~~75 reduction is intended to compensate for exterior shading from landscaping, terrain, and adjacent buildings, as well as dirt and other window obstructions.

The formulas used to calculate the solar heat gain through windows as a function of the angle of incidence are given below in the form of two multipliers: - G_{dir} - the ratio of the solar heat gain to the space relative to direct beam insolation at normal incidence, and G_{dif} - the ratio of solar heat gain to the space relative to the diffuse insolation on a horizontal surface. These ratios have no units of measure.

$$G_{dir} = SHGC_{fen} * Area * \left[fsunlit * CosI * P(CosI) + GrndFac \right] \quad \text{Equation 4.12}$$

and

$$G_{dif} = SHGC_{fen} * Area * DMSHGC * \left(vfSky + vfGrnd * GrndRf \right) \quad \text{Equation 4.13}$$

where

$$P(CosI) = C1 * CosI + C2 * Cos^2 I + C3 * Cos^3 I + C4 * Cos^4 I \quad \text{Equation 4.14}$$

$$GrndFac = vfGrnd \times CosG \times GrndRf \times DMSHGC \quad \text{Equation 4.15}$$

$SHGC_{fen}$ = *Fenestration* Solar Heat Gain Coefficient at normal beam incidence - primary user input [unitless]

CosI = The cosine of the angle of incidence of the direct beam insolation on the window. [unitless]

CosG = The cosine of the angle of incidence of the direct beam insolation on the ground. [unitless]

DMSHGC = Diffuse Multiplier for Solar Heat Gain Coefficient [unitless]

fsunlit = fraction of the window sunlit by direct beam at this hour [unitless]

C1, ...,C4 = polynomial coefficients for angular dependence (cosine of the angle of incidence) of solar heat gain - see Table 4-6.

vfSky = view factor of window to sky [unitless]

vfGrnd = view factor from window to ground [unitless]

GrndRf = Ground Reflectance [unitless] = 0.20

[1717] The justification for changes in this section appears in Eley Associates, *Residential Computer Modeling Draft – Status Report*, March 21, 2002. Presented at the April 2, 2002 workshop.

Table R4-8 Polynomial Coefficients for Angular Dependence

Glazing Type:	Single Pane (1 light)	More Than One Pane (2 or more lights)
$SHGC_{fen}$	0.860	0.695
C1	3.549794	1.881643
C2	-4.597536	1.014431
C3	2.432124	-4.009235-
C4	-0.384382	2.113160
DMSHGC	0.905814	0.828777

4.17 Infiltration/Ventilation

The effective leakage area method of calculating infiltration for conditioned zones was implemented with the 1992 standards and is still used, but Shielding Class 4 is used for infiltration wind speed reduction, based on the description in the 1997 *ASHRAE Handbook of Fundamentals*.

Effective leakage areas with ACMs is specified in terms of a default specific leakage area of 4.9 for designs with ducted HVAC systems and an SLA of 3.8 for nonducted HVAC systems. These Specific Leakage Areas (SLA) are the defaults for the *Proposed Design* and the assumed standard value for the *Standard Design*. The specific leakage area is the ratio of the effective leakage area to the floor area of the building in the same units. The value is increased by 10,000 to provide a more manageable metric.

$$SLA = \left(\frac{ELA}{CFA}\right)\left(\frac{ft^2}{144in^2}\right)(10000) = \left(\frac{ELA}{CFA}\right)69.444 \qquad \text{Equation 4.16}$$

Where:

ELA = Effective leakage area in square inches

CFA = Conditioned floor area

SLA = Specific leakage area

For both the *Standard Design* and the *Proposed Design*, ACMs shall assume that occupants will open the windows if the house becomes “too stuffy.” When natural ventilation, infiltration, and mechanical ventilation fall below a threshold value, the occupants are assumed to open the windows at the beginning of the next hour sufficient to provide an indoor air quality increment which is equal to an additional 0.35 air changes per hour for an eight foot high ceiling. The windows are assumed to remain open and provide this increment of (0.35 air changes per hour) as long as the previous hour’s infiltration, mechanical and natural ventilation rate without this window ventilation for indoor air quality is below the threshold value (see Equations 4.22 through 4.24) Calculation of Infiltration and Ventilation

4.17.1 Calculation of Infiltration and Ventilation

The Effective Leakage Area (ELA) method of calculating infiltration for conditioned zones is documented below and in Chapter 25 of the 1997 ASHRAE Handbook of Fundamentals. The ELA for the *Standard Design* and for the default values for the *Proposed Design* if diagnostic tests are not used, is calculated using the Conditioned Floor Area (CFA) and the Specific Leakage Area (SLA) from Section 4.16 above. (The SLA is the ratio of the effective leakage area to the conditioned floor area of the building, in the same units, multiplied by a factor of 10,000 to provide a more manageable metric.) The energy load on the conditioned space from infiltration heat gains or losses are calculated as follows.

$$CFM_{infil} = ELA \times \sqrt{A \times \Delta T_2 + B \times V^2} \qquad \text{Equation 4.17}$$

$$CFM_{infil+unbalfan} = \sqrt{CFM_{infil}^2 + MECH_{unbal}^2} \quad \text{Equation 4.18}$$

$$CFM_{infil+totfan} = CFM_{infil+unbalfan} + MECH_{bal} \quad \text{Equation 4.19}$$

The volumetric air flow (cfm) due to natural ventilation is derived from the natural ventilation cooling for the hour:

$$CFM_{natv} = \frac{Q_{natv}}{1.08 \times \Delta T_1} \quad \text{Equation 4.20}$$

The total ventilation and infiltration (in cfm) including indoor air quality window operation is:

$$CFM_{total} = CFM_{natv} + CFM_{infil+totfan} + CFM_{iaq} \quad \text{Equation 4.21}$$

The value of CFM_{iaq} depends on the sum of CFM_{natv} and $CFM_{infil+totfan}$ from the previous time step:

When

$$CFM_{natv} + CFM_{infil+totfan} < \frac{(AFT \times CFA)}{7.5} \quad \text{Equation 4.22}$$

then

$$CFM_{iaq} = \frac{(0.35 \times CFA)}{7.5} \quad \text{Equation 4.23}$$

otherwise

$$CFM_{iaq} = 0.000 \quad \text{Equation 4.24}$$

where

CFA = the total conditioned floor area of the residence

AFT = 0.18 for Climate Zones 2 through 15 inclusive, and;

AFT = 0.25 for Climate Zones 1 and 16.

When the windows are opened they provide a ventilation rate equal to 0.35 air changes per hour for a residence of the same floor area but with eight foot high ceilings. CFM_{iaq} simulates the opening of windows to achieve an acceptable indoor air quality by the occupants when ventilation and infiltration from other sources does not provide an adequate quantity of outdoor air to dilute pollutants and refresh the indoor air.

The energy load on the conditioned space from all infiltration and ventilation heat gains or losses is calculated as follows:

$$Q_{total} = 1.08 \times CFM_{total} \times \Delta T_1 \quad \text{Equation 4.25}$$

where

Q_{total} = Energy from ventilation and infiltration for current hour (Btu)

CFM_{infil} = Infiltration in cubic feet per minute (cfm)

$CFM_{infil+unbalfan}$ = combined infiltration and unbalanced mechanical ventilation in cubic feet per minute (cfm)

$CFM_{infil+totfan}$ = infiltration plus the balanced and unbalanced mechanical ventilation in cubic feet per minute (cfm)

$MECH_{bal}$ = the balanced mechanical ventilation in cfm. This value is the smaller of the total supply fan cfm and the total exhaust fan cfm.

$MECH_{unbal}$ = the unbalanced mechanical ventilation in cfm. This value is derived from the absolute value of the difference between the total supply fan cfm and the total exhaust fan cfm.

1.08 = conversion factor in (Btu-min)/(hr-ft^3-°F)

ΔT_1 = difference between indoor and outdoor temperature for current hour (°F)

ΔT_2 = difference between indoor and outdoor temperature for previous hour (°F)

A = stack coefficient, (cfm^2/in^4/ F)

B = wind coefficient, ($cfm^2/in^4/mph^2$)

V = average wind speed for current hour (mph)

ELA= effective leakage area (in^2), measured or calculated using Equation 4.26

The stack (A) and wind (B) coefficients to be used are shown in Table 4-7

Table R4-9 - Infiltration Coefficients

	Floor levels		
Coefficient	**one**	**two**	**three**
A (stack)	0.0156	0.0313	0.0471
B (wind) (Shielding Class 4)	0.0039	0.0051	0.0060

The ELA is calculated from the SLA as follows:

$$ELA = CFA \times SLA \times \left(\frac{144\ in^2}{1\ ft^2}\right) \times \left(\frac{1}{10{,}000}\right)$$ Equation 4.26

where

CFA = conditioned floor area (ft^2)

SLA = specific leakage area (ft^2/ft^2)

ELA = effective leakage area (in^2)

Alternatively, ELA and SLA may be determined from blower door measurements:

$$ELA = 0.055 \times CFM50_H$$ Equation 4.27

where

$CFM50_H$ = the measured air flow in cubic feet per minute at 50 pascals for the dwelling with air distribution registers unsealed.

Substituting Equation 4.27 into Equation 4.16 gives the relationship of the measured air flow rate to SLA:

$$SLA = 3.819 \times \frac{CFM50_H}{CFA}$$ Equation 4.28

ACM users may take credit for reduced infiltration and mechanical ventilation for low-rise, single-family dwellings when verified by site diagnostic testing. The model for infiltration allows for reduced infiltration entries but also assumes that dwelling occupants will open windows when natural ventilation and infiltration do not provide adequate air quality. When infiltration falls below the threshold described in Equation 4.22, ACMs shall assume that occupants open windows in the next hour and add window ventilation to supplement the infiltration and cooling ventilation to achieve an effective air change rate consistent with ASHRAE Standard 62-1989 as described in Equations 4.20 and 4.21.

The Effective Leakage Area (ELA) of the dwelling may be reduced and the algorithm will result in less energy use due to infiltration unless window ventilation is needed. Lower ELAs will result in more frequent window ventilation and at some point higher energy use. Air quality ventilation may also be added and if this ventilation plus infiltration and cooling ventilation provides adequate air exchange, window ventilation will no longer occur or will occur very infrequently. The energy use of both ventilation exhaust fans and ventilation supply fans must be entered. These ventilation fans are assumed to operate continuously and the energy use of these fans must be included as energy use in the energy budget calculated for the dwelling. Except for the set 0.5 SLA reduction credits, both reduced ELA/SLA and ventilation fans are conditions which require field verification or diagnostic testing by a HERS rater and must be reported in the *HERS Required Verification* listings on the Certificate of Compliance and the Computer Method Summary forms. Controlled ventilation crawl spaces (CVC) and sunspaces are modeled using the air changes per hour method. Modeling of CVC's and sunspaces are optional capabilities covered in Sections 6.1 and 6.3, respectively. All optional capabilities that are used in the *Proposed Design* must be reported in the *Special Features and Modeling Assumptions* listings on the Certificate of Compliance and the Computer Method Summary forms.

4.18 Heating Equipment and Air Distribution Fans

The efficiency of fossil-fuel-fired heating equipment (furnaces, boilers, etc.) is rated as an Annual Fuel Utilization Efficiency (AFUE) . The test method for calculating AFUE ignores electric energy used by air distribution fans and the contribution of the fan motor input to the heating output. The fan energy is calculated at the rate of 0.005 watt-hours per Btu of heat delivered by the equipment.

The vast majority of residential furnaces have the fan motor in the air stream so the heat generated by the motor contributes to heating the house. This effect may be considered in calculating the source energy for heating.

The heating source energy may be calculated using an effective AFUE which accounts for both the heat contribution of the fan and the source energy used by the fan. The effective AFUE is a similar number to the seasonal efficiency used in pre 1992 ACMs.

$$AFUE_{eff} = \frac{1 + 0.005(3.413)}{\frac{1}{AFUE} + 0.005(10.239)}$$ Equation 4.29

~~The effective AFUE is used for all furnaces and boilers that use ducted distribution systems.~~

4.19 Duct Efficiency

The Commission has approved algorithms and procedures for determining duct and HVAC distribution efficiency. Details are presented in Appendix F for Seasonal efficiency and in Appendix P for hourly ACM efficiency calculations.

There are two calculation procedures to determine seasonal air distribution efficiency using either 1) default input assumptions or 2) diagnostic measurement values. Air distribution efficiencies for heating and cooling shall be calculated separately. The ACM shall require the user to choose values for the following parameters to calculate seasonal duct efficiencies as shown below. The ACM shall use the defaults shown in [brackets] for the *Standard Design*[18].:

1. Location of the duct system [ducts in the attic]
2. Insulation level of ducts [R 4.2]
3. The surface area of ducts or separate supply and return surface areas [27% of conditioned floor area (CFA) for supply duct surface area; 5% CFA for return duct surface area in single story dwellings and 10% CFA for return duct surface area in dwellings with two or more stories] or the installer measured and HERS rater verified reduced surface area of supply ducts in conjunction with ~~ACCA Manual D~~a complete design and installer measured and HERS rater verified adequate air ~~fan flow consistent with the ACCA Manual D design as specified in 5. below.~~as specified in Section 4.28.
4. The leakage level of the duct system [6% of fan flow]. Two values are possible for the proposed design: 6% of fan flow if installer measured and HERS rater verified at no more than 6% of fan flow, otherwise 22% of fan flow shall be used.
5. ~~ACCA manual D design, duct layout and system fan flow [No]. This requires that engineering calculations and a duct layout have been prepared as part of the building plans and that system fan flow specified in those calculations be installer measured and HERS rater verified.~~
6. Designation for systems with less than 12 feet of duct outside conditioned space [No].
7. Attic duct efficiency with radiant barrier in accordance with Package D requirements [Yes in climate zones where required by Package D, otherwise No].

When any duct efficiency credit is claimed beyond the default assumptions that requires diagnostic testing or verification by a HERS rater or the local enforcement agency, i.e. when non-default values (except HVAC equipment capacities) are used to determine duct efficiency, the leaks in the air distribution system connections shall not be sealed with cloth back rubber adhesive duct tapes unless such tape is used in combination with mastic and drawbands and this requirement must be specified in the *Special Features and Modeling Assumptions* listings and the *HERS Required Verification* listings on the CF-1R and the C-2R.

The ACM shall automatically use the following values from the description of the *Proposed Design* when calculating the distribution system efficiency:

- Number of stories
- Building Conditioned Floor Area
- Building Volume
- Floor Type
- Presence of attic radiant barrier or cool roof

[18] All proposed designs may model additional insulation (R>4.2) for ducts when installed. The R-value modeled must be the minimum installed insulation level for the entire duct system except as noted in Appendix F even though part of the ducts may serve unmodeled dwellings or spaces.

- Presence of insulation between floor above crawlspace or unconditioned basement, and on or within crawlspace or basement walls adjacent to outside conditions or the ground below
- Outdoor summer and winter design temperatures for each climate zone

When more than one HVAC system serves the building or dwelling, the HVAC distribution efficiency is determined for each system and a~~n~~ conditioned floor area-weighted average seasonal efficiency is determined based on the inputs for each of the systems.

When an existing HVAC system is extended to serve an addition, the default assumptions for duct and HVAC distribution efficiency must be used for both the *Proposed Design* and the *Standard Design*. However, when a new, high efficiency HVAC distribution system is used to serve the addition or the addition and the existing building, that system may be modeled to receive energy credit subject to diagnostic testing and verification of proper installation by a HERS rater.

4.20 Absorptivity

Standard Design: In the *Standard Design* run, the absorptivity of all surfaces is assumed to be the same as the *Proposed Design*.

Proposed Design: In the *Proposed Design*, the absorptivity of walls or other surfaces adjacent to unconditioned spaces, such as crawl space floors and walls adjacent to attached garages, may be assumed to be zero, otherwise all surfaces shall be assumed to have an absorptivity of 0.50.

4.21 Water Heating Calculations ~~Method~~

The water heating budget is the TDV energy that would be used by a system that meets the requirements of the standards. The calculation procedure is documented in ACM RN-2005.

~~This section describes the calculation methods to use with residential water heating systems. The equations listed here must be implemented exactly in general purpose ACMs.~~

~~4.21.1Water Heating Energy Use~~

~~The total water heating energy use is the water heating energy use summed over all water heating systems, all water heaters, and all dwelling units being modeled.~~

$$\cancel{WHEU_{tot} = \sum_{k=1}^{M} (WHEU_k \times NmbrWHtr_k)} \qquad \text{Equation 4.30}$$

~~For the *Proposed Design*, Equation 4.31 applies:~~

$$WHEU_{proposed} = WHEU_{tot} \ x \ \frac{1000}{CFA_{tot}} \qquad \text{Equation 4.31}$$

$$CFA_{tot} = \sum_{i=1}^{N} CFA_i \qquad \text{Equation 4.32}$$

~~Where:~~

~~$WHEU_{tot}$~~	~~=~~	~~total water heating energy use~~
~~$WHEU_k$~~	~~=~~	~~water heating energy use for the k^{th} water heating system~~
~~$NmbrWHtr_k$~~	~~=~~	~~number of water heaters in k^{th} water heating system~~
~~CFA_i~~	~~=~~	~~conditioned floor area of the i^{th} dwelling unit (ft^2). The CFA is limited to a maximum of 2,500 ft^2~~
~~N =~~		~~Number of dwelling units.~~

~~4.21.2 Water Heating Energy Budget~~

~~The water heating energy budget (WHEB) for a water heating system or a building is determined from the following equation. The budget may be calculated for a system that serves a set of dwelling units or for the entire building. The budget for individual units in a multi-family applications may be expressed as a total, as shown in Equation 4.33.~~

$$\text{WHEB} = 0.00485 \times \sum_{i=1}^{N} CFA_i + 16.37N \qquad \text{Equation 4.33}$$

~~Where CFAi and N are as described in Section 4.21.1~~

~~4.21.3 Water Heating Systems~~

~~Water heating distribution systems may serve more than one dwelling unit and may have more than one piece of water heating equipment. The energy used by a water heating system is calculated as the sum of the energy used by each individual water heater in the system. Energy used for the whole building is calculated as the sum of the energy used by each of the water heating systems. To delineate different water heating elements several indices are used.~~

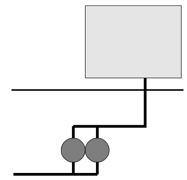
~~i Used to describe an individual dwelling unit. For instance CFA_i would be the conditioned floor area of the ith dwelling unit. "N" is the total number of dwelling units.~~

~~j Used to refer to the number of water heaters in a system. "M" is the total number of water heaters.~~

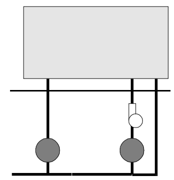
~~k Used to refer to a water heating system or distribution system. A building can have more than one system and each system can have more than one water heater.~~

~~The following diagrams illustrate some of the cases that are recognized by the Commission water heating method.~~

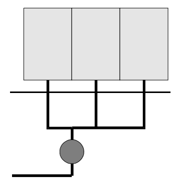
~~1~~ ~~One distribution system with two water heaters serving a single dwelling unit.~~



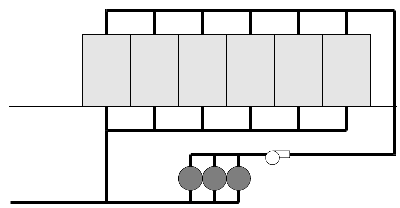
~~2~~ *~~Two distribution systems, each with a single water heater serving a single dwelling unit.~~*



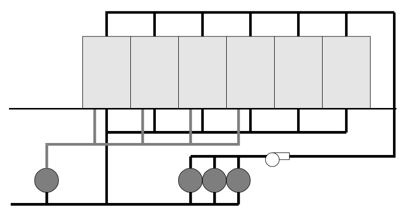
~~3~~ ~~One distribution system with one water heater serving multiple dwelling units.~~



4 ~~Single distribution system with multiple water heaters serving multiple units.~~



~~5~~ ~~Two distribution systems, one with multiple water heaters serving multiple dwelling units. The recirculating distribution system serves all the units. The other serves only four units.~~



~~The following rules apply to the calculation of water heating system energy use:~~

- ~~1 water heater type per system~~
- ~~1 solar or woodstove credit (but not both) per system~~

~~4.21.4 Adjusted Recovery Load (ARL)~~

~~The adjusted recovery load is calculated separately for each water heating distribution system,~~ ~~*k*.~~ ~~It accounts for the number of units served, the size of each unit and the type of distribution system.~~ ~~ARL_k is given by the following equations for the kth distribution system.~~

~~$ARL_k = SRL_k\ DSM_k\ SSM_k$~~ ~~Equation 4.34~~

~~Where~~

~~SRL_k = Standard water heating recovery load of the kth water heating distribution system (million Btu/yr).~~

~~DSM_k = Distribution system multiplier (unitless) for the kth water heating system. A value of one is used for standard distribution systems. (See Table 4-8)~~

~~SSM_k = Solar savings multiplier (unitless) for the kth water heating system. See equation below.~~

~~$SSM_k = 1 - (SSF_k\ A)$ Equation 4.35~~

~~SSF_k = Solar savings fraction taken from an f-Chart analysis or other approved method (unitless).~~

~~A = Adjustment to the SSF (unitless). This value is 0.80 to account for pumping energy and piping heat loss effects when these losses are not accounted for in the f-Chart analysis and 1.00 for passive systems (no circulation pump) and systems where pump energy and piping losses were included in the f-Chart analysis. (Piping loss effects are accounted for in the Commission Passive Solar Credit calculation procedure). Approved ACM compliance supplements shall state that pipe losses are not to be accounted for in the f-Chart analysis of active solar water heating systems.~~

~~When a water heating system has more than one water heater, the total load on the system is assumed to be shared equally by each water heater. The ARL for the jth water heater is then shown in the following equation.~~

$$ARL_j = \frac{ARL_k}{NmbrEquip_k} \quad \text{Equation 4.36}$$

~~Where~~

~~$NmbrEquip_k$ = The number of water heaters in the kth system.~~

~~4.21.4.1 Standard Recovery Load~~

~~The standard water heating recovery load for the kth system is the load assuming a standard distribution system and no solar or wood stove credits. It depends on the size of the dwellings and number of units and is given in the following equation (million Btu/yr).~~

$$SRL_k = \sum_{i=1}^{n} \frac{0.0855347\left(\frac{CFA_i}{1000}\right)^2 + 3.61307\left(\frac{CFA_i}{1000}\right) + 6.036}{NmbrSys_i} \quad \text{Equation 4.37}$$

~~Where~~

~~CFAi = Conditioned floor area of the ith dwelling unit served by the water heater (ft^2). The CFA is limited to a maximum of 2,500 ft^2 per dwelling unit.~~

~~n = Number of dwelling units served by the kth water heating system.~~

~~$NmbrSys_i$ = Number of water heating systems that serve the ith dwelling unit. When a dwelling unit is served by more than one system, the assumption is that the load is shared equally by each system.~~

~~4.21.4.2 Distribution System Multiplier~~

~~The distribution system multiplier (unitless) is an adjustment for alternative water heating distribution systems. A value of one is used for standard distribution systems. Values for other systems are given in the following table~~

~~Table R 4-10 - Distribution System Multipliers (DSMs)~~

Distribution System		DSM - Single Family	DSM-MultiFamily
Standard		1.00	1.00
POU		0.82	na
HWR		0.82	na
Pipe Insulation		0.92	0.92
Parallel Piping		0.86	0.86
Recirc/NoControl		1.52	1.52
Recirc/Timer		1.28	na
Recirc/Temp		1.05	1.05
Recirc/Demand		0.98	na
Recirc/Time+Temp		0.96	na
Recirc/Demand + HWR		0.80	na
Recirc/Demand + Pipe Insulation		0.90	na

4.21.5 Energy Use of Individual Water Heaters

Once the adjusted recovery load is determined for each water heater, the energy use for each water heater is calculated as described below for each water heater type.

4.21.5.1 Storage Gas, Storage Electric and Heat Pump Water Heaters

The energy use of storage gas, storage electric and heat pump water heaters is given by the following equation.

$$WHEU_j = \left[\frac{ARL_j \times HPAF_j}{LDEF_j}\right] WSAF_j \qquad \text{Equation 4.38}$$

Where

$WHEU_j$ = Energy use of the water heater (millions Btu/yr), adjusted for tank insulation and wood stove boilers.

ARL_j = Adjusted recovery load (millions Btu/yr). Equations for this value are given in Section 4.21.4.

SEM_j = Source energy multiplier (unitless). This multiplier is 3.0 for electric and heat pump water heaters and 1.0 for gas or oil water heaters.

$HPAF_j$ = Heat pump adjustment factor from the table below based on climate zone. This value is one for storage gas, storage oil and storage electric water heaters.

~~*Table R4-11 - Heat Pump Adjustment Factors*~~

~~Climate Zone~~	~~Heat Pump Adjustment Factor~~	~~Climate Zone~~	~~Heat Pump Adjustment Factor~~
~~1~~	~~1.040~~	~~9~~	~~0.920~~
~~2~~	~~0.990~~	~~10~~	~~0.920~~
~~3~~	~~0.990~~	~~11~~	~~0.920~~
~~4~~	~~1.070~~	~~12~~	~~1.070~~
~~5~~	~~1.070~~	~~13~~	~~0.920~~
~~6~~	~~0.920~~	~~14~~	~~1.040~~
~~7~~	~~0.920~~	~~15~~	~~0.920~~
~~8~~	~~0.920~~	~~16~~	~~1.500~~

~~$LDEF_j$ = The load dependent energy factor (LDEF) is given by the following equation. This equation adjusts the standard EF for different load conditions.~~

$$\cancel{LDEF_j = \ln\left(\frac{ARL_j \times 1000}{365}\right)\left(a \times EF_j + b\right) + \left(c \times EF_j + d\right)}$$ ~~Equation 4.39~~

~~a,b,c,d = Coefficients from the table below based on the water heater type.~~

~~*Table R4-12 - LDEF Coefficients*~~

~~Coefficient~~	~~Storage Gas~~	~~Storage Electric~~	~~Heat Pump~~
~~A~~	~~-0.098311~~	~~-0.91263~~	~~0.44189~~
~~B~~	~~0.240182~~	~~0.94278~~	~~-0.28361~~
~~C~~	~~1.356491~~	~~4.31687~~	~~-0.71673~~
~~D~~	~~-0.872446~~	~~-3.42732~~	~~1.13480~~

~~EF_j = Energy factor of the water heater (unitless). This is based on the DOE test procedure.~~

~~$WSAF_k$ = Wood stove boiler adjustment factor for the kth water heating system. This is given in Section 4.21.5.5. This is an optional capability and is set to 1.00 for ACMs without wood stove boiler modeling capability.~~

~~*4.21.5.2Instantaneous Gas or Oil*~~

~~The energy use for instantaneous gas or oil water heaters is given by the following equation.~~

$$\cancel{WHEU_j = \left[\frac{ARL_j \times SEM_j}{EF_j} + \frac{PILOT_j \times 8760}{1000000}\right] WSAF_j}$$ ~~Equation 4.40~~

~~Where~~

~~ARL_j = Adjusted recovery load from Section 4.21.4..~~

~~SEM_j = Source energy multiplier (unitless). This multiplier is 1.0 for gas or oil water heaters and can therefore be ignored.~~

~~EF_j = Energy factor from the DOE test procedure (unitless). This is taken from manufacturers literature or from the CEC Appliance Database.~~

~~$PILOT_j$ = Energy consumption of the pilot light (Btu/h).~~

~~$WSAF_k$ = Wood stove boiler adjustment factor for the kth water heating system. This is given in Section 4.21.5.5. This is an optional capability and is set to 1.00 for ACMs without wood stove boiler modeling capability.~~

~~*4.21.5.3 Instantaneous Electric*~~

~~Energy use for instantaneous electric water heaters is given by the following equation.~~

$$\cancel{WHEU_j = \left[\frac{ARL_j \times SEM_j}{EF_j}\right] WSAF_j} \qquad \text{~~Equation 4.41~~}$$

~~ARL_j = Adjusted recovery load from Section 4.21.4.~~

~~SEM_j = Source energy multiplier (unitless). This multiplier is 3.0 for electric water heaters.~~

~~EF_j = Energy factor from DOE test procedure (unitless).~~

~~$WSAF_k$ = Wood stove boiler adjustment factor for the kth water heating system. This is given in Section 4.21.5.5. This is an optional capability and is set to 1.00 for ACMs without wood stove boiler modeling capability.~~

~~*4.21.5.4 Large storage gas and Indirect Gas*~~

~~Energy use for large storage gas and indirect gas water heaters is given by the following equation. Note: large storage gas water heaters are defined as any gas storage water heater with an input rate not less than 75,000 Btu/h.~~

$$\cancel{WHEU_j = \left[\frac{ARL_j + \left(JL_j\right)}{EFF_j \times EAF_j} + PILOT_j\left(\frac{8760}{1000000}\right)\right] WSAF_j} \qquad \text{~~Equation 4.42~~}$$

~~[SBL_j has been deleted from this equation]~~

~~Where~~

~~ARL_j = Adjusted recovery load (defined later).~~

~~JLj= Jacket loss (millions Btu/yr). Equations are given in Section 4.21.7.~~

~~EFF_j = Efficiency (fraction, not %). To be taken from CEC Appliance Database or from manufacturers literature. These products may be rated as a recovery efficiency, thermal efficiency or AFUE.~~

~~EAF_j = Efficiency adjustment factor (unitless). This value is 1.0 for large storage gas water heaters and 0.98 for indirect gas water heaters.~~

~~$PILOT_j$ = Pilot light energy (Btu/h).~~

~~$WSAF_k$ = Wood stove boiler adjustment factor for the kth water heating system. This is given in Section 4.21.5.5. This is an optional capability and is set to 1.00 for ACMs without wood stove boiler modeling capability.~~

~~4.21.5.5 Wood Stove Adjustment Factors~~

~~This is an optional capability and the Wood Stove Boiler Adjustment Factor is set to 1.00 for ACMs without wood stove boiler modeling capability. The wood stove adjustment factor (unitless) reduces water heating energy to account for the heat contribution of wood stove boilers. This multiplier is taken from the table below, based on climate zone and whether or not the wood stove boiler has a recirculation pump. The inclusion of this factor and its relevant input parameters is an optional capability for ACMs. However, when this optional capability is implemented the algorithms and procedures given below must be used.~~

~~Table R4- 13 - Wood Stove Adjustment Factors~~

~~Climate Zone~~	~~Wood Stoves with Pumps~~	~~Wood Stoves without Pumps~~
~~1~~	~~0.775~~	~~0.750~~
~~2~~	~~0.775~~	~~0.750~~
~~3~~	~~0.775~~	~~0.750~~
~~4~~	~~0.865~~	~~0.850~~
~~5~~	~~0.865~~	~~0.850~~
~~6~~	~~0.910~~	~~0.900~~
~~7~~	~~0.910~~	~~0.900~~
~~8~~	~~0.955~~	~~0.950~~
~~9~~	~~0.910~~	~~0.900~~
~~10~~	~~0.955~~	~~0.950~~
~~11~~	~~0.910~~	~~0.900~~
~~12~~	~~0.865~~	~~0.850~~
~~13~~	~~0.910~~	~~0.900~~
~~14~~	~~0.910~~	~~0.900~~
~~15~~	~~1.000~~	~~1.000~~
~~16~~	~~0.730~~	~~0.700~~

~~4.21.6 Tank Surface Area~~

~~Tank surface area (TSA) is used to calculate the jacket loss (JL) for large storage gas and indirect gas water heaters. TSA is given in the following equation as a function of the tank volume.~~

$$\cancel{TSA_j = e\,(f\ VOL_j^{0.33} + g)^2} \qquad \text{Equation 4.43}$$

~~Where~~

~~VOL_j = Actual tank capacity (gallons).~~

~~e,f,g = Coefficients given in the following table.~~

~~*Table R4-14 - Coefficients for Calculating Tank Surface Areas*~~

~~Coefficient~~	~~Storage Gas~~	~~Large Storage Gas and Indirect Gas~~	~~Storage Electric and Heat Pumps~~
~~e~~	~~0.00793~~	~~0.01130~~	~~0.01010~~
~~f~~	~~15.67~~	~~11.8~~	~~11.8~~
~~g~~	~~1.9~~	~~5.0~~	~~5.0~~

~~4.21.7Jacket Loss~~

~~The jacket loss for large storage gas and indirect gas water heaters~~

$$JL_j = \left(\frac{TSA_j(135-60.3)}{RTI_j + REI_j} + (FTL_j)(EFF_j)(EAF_j) \right)\left(\frac{8760}{1000000} \right) \quad \text{Equation 4.44}$$

~~Where~~

~~TSA_j = Tank surface area (ft²).~~

~~FTL_j = Fitting losses[19]. This is a constant 61.4 Btu/h.~~

~~REI_j = R-value of exterior insulating wrap.~~

$$RTI_j = \left(\frac{TSA_j(135-60.3)}{(8.345(VOL_j)(SBL_j)(135-60.3) - FTL_j - PILOT_j)(EFF_j)(EAF_j)} \right) \quad \text{Equation 4.45}$$

~~SBLj = Standby loss expressed as a fraction of the heat content of the stored water lost per hour from the CEC Appliance Database or from manufacturer's literature.~~

~~Where EFF_j and EAF_j are efficiencies as described in *Section 4.21.5.4*~~

~~*4.22 Slab Heat Loss (F2 Factor)*~~

~~See Section 4.7.1.~~

NOTE, RENUMBER SECTIONS FROM HERE ON

4.22 Fenestration Products

Information concerning fenestration products, specifically the default table for fenestration U-values and the default table for fenestration SHGC values, is included in Sections 101 and 116 of Title 24, Part 6, the energy efficiency standards for buildings.

4.23 Radiant Barriers

Standard Design: The *Standard Design* has a radiant barrier in accordance with Package D requirements.

19 See Davis Energy Group report, Section III, Page A-8.

Proposed Design: Radiant barriers are modeled by calculating ceiling U-value modifiers that are functions of the ceiling insulation and the season and by using different seasonal attic temperatures for attics with radiant barriers which result in better HVAC distribution efficiencies for ducts in the attic below a radiant barrier.

Radiant barriers must meet specific eligibility and installation criteria to be modeled by any ACM and receive energy credit for compliance with the energy efficiency standards for low-rise residential buildings.

- The emittance of the radiant barrier must be less than or equal to 0.05 as tested in accordance with ASTM C-1371-9~~7~~8 or ASTM E408-71(1996)e1.
- Installation must be in conformance with ASTM C-1158-97 (Standard Practice For Use and Installation Of Radiant Barrier Systems (RBS) In Building Construction.), ASTM C-727-90(1996)e1 (Standard Practice For Installation and Use Of Reflective Insulation In Building Constructions.), ASTM C1313-97~~5~~ (Standard Specification for Sheet Radiant Barriers for Building Construction Applications), and ASTM C-1224-99~~3~~ (Standard Specification for Reflective Insulation for Building Applications) and the radiant barrier must be securely installed in a permanent manner with the shiny side facing down toward the attic floor. Moreover, radiant barriers must be installed to the roof truss/rafters (top chords) in ***any*** of the following methods, with the material:

  1. Draped over the truss/rafter (the top chords) before the upper roof decking is installed.
  2. Spanning between the truss/rafters (top chords) and secured (stapled) to each side.
  3. Secured (stapled) to the bottom surface of the truss/rafter (top chord). A minimum air space must be maintained between the top surface of the radiant barrier and roof decking of not less than 1.5 inches at the center of the truss/rafter span.
  4. Attached [laminated] directly to the underside of the roof decking. The radiant barrier must be laminated and perforated by the manufacturer to allow moisture/vapor transfer through the roof deck.

In addition, the radiant barrier must be installed to cover all gable end walls and other vertical surfaces in the attic.

- The attic must be ventilated to:

  1. conform to manufacturer's instructions.
  2. provide a minimum free ventilation area of not less than one square foot of vent area for each 150 square feet of attic floor area.
  3. provide no less than 30 percent upper vents.

(Ridge vents or gable end vents are recommended to achieve the best performance. The material should be cut to allow for full air flow to the venting.)

- The radiant barrier (except for radiant barriers laminated directly to the roof deck) must be installed to:

  1. have a minimum gap of 3.5 inches between the bottom of the radiant barrier and the top of the ceiling insulation to allow ventilation air to flow between the roof decking and the top surface of the radiant barrier have a minimum of six (6) inches (measured horizontally) left at the roof peak to allow hot air to escape from the air space between the roof decking and the top surface of the radiant barrier.

- When installed in enclosed rafter spaces where ceilings are applied directly to the underside of roof rafters, a minimum air space of 1 inch must be provided between the radiant barrier and the top of the ceiling insulation, and ventilation must be provided for every rafter space. Vents must be provided at both the upper and lower ends of the enclosed rafter space.
- The product must meet all requirements for California certified insulation materials [radiant barriers] of the Department of Consumer Affairs, Bureau of Home Furnishings and Thermal Insulation, as specified by CCR, Title 24, Part 12, Chapter 12-13, Standards for Insulating Material.
- The use of a radiant barrier and the criteria specified above for covering all gable end walls and other vertical surfaces in the attic, and for providing attic ventilation shall be listed in the *Special Features and*

Modeling Assumptions listings of the CF-1R and C-2R and described in detail in the ACM Compliance Supplement.

For the heating season, Equation 4.46 is the expression for the U-value modifier; for the cooling season, Equation 4.47. To determine the U-value for a ceiling with a radiant barrier, multiply the U-value of the ceiling assembly without the radiant barrier times the U-value modifier. The U-value modifiers are calculated from equations 4.46 and 4.47.

For installed insulation greater than R-8:

$$UvalMod_{heating} = (-11.404 \times U^2) + (0.21737 \times U) + 0.92661 \qquad \text{Equation 4.46}$$

$$UvalMod_{cooling} = (-58.511 \times U^2) + (3.22249 \times U) + 0.64768 \qquad \text{Equation 4.47}$$

Otherwise these modifiers are 1.000.

4.24 Cool Roofs

Standard Design: The *Standard Design* does not have a cool roof.

Proposed Design: Cool roofs are assumed to have an impact equal to the cooling savings for radiant barriers. The calculations are the same as described in section 4.24 except that $UvalMod_{heating}$ (equation 4.26) is assigned a value of 1.0. In the event that both a cool roof and radiant barrier is specified, there is no credit for the cool roof.

Cool roofs must meet specific eligibility and installation criteria to receive energy credit for compliance as described in the standards and this section. In general, the solar reflectance must be 0.4 or higher for tile roofs or 0.7 or higher the other roof materials; and the emittance must be 0.75 or higher. The use of a cool roof shall be listed in the *Special Features and Modeling Assumptions* listings of the CF-1R and C-2R and described in detail in the ACM Compliance Supplement.

Acrylic or elastomeric l~~L~~iquid applied roofing products shall be applied at a minimum dry mil thickness of 20 mils across the entire roof surface, and meet the minimum performance requirements of ASTM D6083-97a when tested in accordance with ASTM D6083-97a for the following key properties:

* Initial Tensile Strength

* Initial Elongation

* Elongation After 1000 Hours Accelerated Weathering

* Permeance

* Accelerated Weathering

~~Effective January 1, 2003, all~~ All products qualifying for this credit will be required to meet the Cool Roof Rating Council testing, certification and labeling requirements described in Section 10-113 of the standards. ~~Prior to January 1, 2003, the solar reflectance shall be measured in accordance with ASTM E1918-97 or ASTM E903-96. Emittance shall be measured in accordance with ASTM E408-71(1996)e1. The solar reflectance and emittance shall be certified by the manufacturer and reported in product literature.~~

4.25 No Cooling

Standard Design: The *Standard Design* has a cooling system as described in Section 3.8.2. for a central ducted cooling system the same as the *Proposed Design*.

Proposed Design: Where no air conditioning system is proposed for use, the *Proposed Design* is required to model a split system air conditioner with an SEER of 10.0 with R-4.2 ducts located in the attic with *Standard Design* default duct characteristics and a thermostatic expansion valve in accordance with Package D.

4.26 Commission Equivalent Efficiencies

The approved ACM compliance supplement must include the following conversion and substitution:

For equipment without an HSPF rating, the HSPF may be calculated as:

- HSPF = (3.2 x COP) - 2.4 Equation 4.48
- The EER may be used in lieu of the SEER for equipment not required to be tested for an SEER rating.

4.27 Air Conditioning Systems[20]

Air conditioning systems shall be sized, installed, tested and modeled according to the provisions of this section.

4.27.1 Compressor Sizing

The Design Cooling Capacity shall be calculated using the procedure in Appendix L. The Maximum Allowable Cooling Capacity shall be calculated using the procedure in Appendix M. For ACM energy calculations all loads are met in the hour they occur regardless of the compressor size.

4.27.2 Cooling System Refrigerant Charge

Proper refrigerant charge is necessary to allow the electrically driven compressor air conditioning system to operate at full capacity and efficiency. The presence of a thermostatic expansion valve (TXV) mitigates the impact of charge problems. Based on field measurements, typical California air conditioning systems are assumed to be installed without proper charge and for ACM energy calculations the Ftxv factor is set to 0.90 to account for the impact of this condition. If the system is properly charged or a TXV is installed, certified and verified according to the procedures of Appendix K the Ftxv factor may be set to 0.96 for ACM energy calculations

4.27.3 Air Handler Fan Flow

The efficiency of an air conditioning system is affected by the flow of conditioned air through the system. Cooling system air flow is specified in cubic feet per minute per ton (cfm/ton) where one ton of capacity is 12,000 Btu/hour at ARI rated conditions. Table 4.28-1 shows the criteria used for calculations and measurement of air flow for cooling systems. Cooling Air Flow is the flow achieved under normal air conditioning operation with the cooling coil wet from condensation. If a flow test is done using the fan only switch on the air handler the coil will be dry allowing higher air flow and the Dry Coil critera shall be used.

Table R4-15 Air flow Criteria

Test and Condition	**Cooling air flow (Wet Coil)**	**Test flow if Dry Coil**
Default Cooling Air Flow	300 cfm/ton	N/A

[20] The justification for changes in this section appears in Pacific Gas and Electric Company, *Time Dependent Valuation (TDV) – Economics Methodology, Code Change Proposal*, April 2, 2002. Presented at the April 2, 2002 workshop.

Fan at cooling speed		
Sufficient Flow for Valid Standard Refrigerant Charge Test Fan at cooling speed.	350 cfm/ton **OR** Passes temperature split test	400 cfm per ton
Adequate Air Flow. Fan at cooling speed	400 cfm/ton	450 cfm per ton

4.27.4 Default Cooling Air Flow

Default cooling air flow shall be assumed in calculations for any system in which the air flow has not been tested, certified and verified. For ACM energy calculations the Fair multiplier shall be set to 0.925 for systems with default cooling air flow.

4.27.5 Sufficient Flow for Valid Standard Refrigerant Charge Test

This level of flow is required in order to ensure that the refrigerant charge procedure in Appendix K will produce valid results. Either the flow measurement procedure of Appendix O or the temperature split test of Appendix K may be used to demonstrate Sufficient Air Flow. No credit is allowed for ACM energy calculations and the Fair multiplier shall be set to 0.925.

4.27.6 Adequate Air Flow

Adequate air flow is required to allow air conditioning systems to operate at their full efficiency and capacity. Credit may be taken for adequate air flow in ACM calculations by setting the Fair factor to 1.0 but flow must be tested, certified and verified using the procedures of Appendix O. When an Adequate Air Flow Credit is claimed, the duct design, layout, and calculations must also be submitted to the local enforcement agency and a certified HERS rater.

The installer shall measure and certify the air flow. The certified HERS rater shall verify the existence of the duct design layout and calculations, verify that the field installation is consistent with this design. and verify the air flow rate.

4.27.7 Compressor Energy

ACMs shall use the following inputs and algorithms to calculate the energy use of electrically driven compressor type air conditioning systems.

Inputs:

DBt = Outdoor dry bulb temperature for the hour from weather file

Cloadhr = Space Sensible Cooling Load for the hour from the ACM simulation, Btu

CDE = Seasonal Cooling Duct Efficiency from Appendix F

CDEMhr = Cooling Duct Efficiency Multiplier for the hour calculated according to Appendix P

SEER = Seasonal Energy Efficiency Ratio for the air conditioner

Ftxv = the refrigerant charge factor, default = 0.9. For systems with a verified TXV or verified refrigerant charge, the factor shall be 0.96. See Section 4.28.2.

Fair = the system air flow factor, defaults = 0.925. For systems with air flow verified, Fair shall be 1. See Section 4.28.3.

EER = Energy Efficiency Ratio at ARI test conditions, if not input, defaults to Table 4-15.

Table R4-16 - Default EER

SEER	EER
SEER <11.5	10-(11.5-SEER)*0.83
11.5<= SEER	10

The SEERnf and EERnf energy efficiency ratios without distribution fan consumption, adjusted for refrigerant charge and air flow shall be calculated using equation 4.28.a

$$SEER(EER)nf = (1.0035*X + 0.011*X^2 + 0.00024\ X^3)*Ftxv*Fair \qquad \text{Eqn 4.28.a}$$

The energy efficiency ratio at current dry bulb temperature, EERt, shall be calculated according to Table 4-16.

Table R4-17 - EERt = Energy Efficiency Ratio at current DBt

DBt	EERt
<83 F	SEERnf
83<DBt<95	SEERnf+((DBt-82)*(EERnf-SEERnf)/13)
>94	EERnf-(DBt-95)*0.12

The sensible energy efficiency at the current outdoor temperature shall be calculated using Equation 4.28.b

$$CEt = EERt * (0.88+0.00156*(Dbt-95) \qquad \text{Eqn 4.28.b}$$

Compressor watt hours for the current hour of the simulation shall be calculated using Equation 4.28.c

$$CompWhr = (Cloadhr*CDEMhr)/(CDE* CEt) \qquad \text{Eqn 4.28.c}$$

4.27.8 Air Handler Fan Energy

Inputs

FanW/Btu = Fan watts per Btu of rated cooling capacity, default 0.051 W/Btu

The default value shall be used for the Standard design. Alternate FanW/Btu may be used in ACM calculations for the Proposed design if the actual installed fan watts are less than or equal to the simulation value based on measurements certified by the installer and verified by a rater using the procedure in Appendix O.

Cooling fan energy consumption for each hour shall be calculated using Equation 4.28.d

$$FanWhr = FanW/Btu * Cloadhr*CDEMhr/ DCE \qquad \text{Eqn 4.28.d}$$

4.27.9 Cooling Electric Energy Calculation

The ACM shall calculate the hourly cooling electricity consumption in kWh using Equation 4.28.e

$$ACkWhr = (FanWhr + CompWhr)/ 1000 \qquad \text{Eqn 4.28.e}$$

4.28 Heating Systems

Heating systems modeled according to the provisions of this section.

ACMs shall use the following inputs and algorithms to calculate heating energy use.

Inputs:

DBt = Outdoor dry bulb temperature for the hour from weather file

Hloadhr = Space Heating Load for the hour from the ACM simulation, Btu

HDE = Seasonal Heating Duct Efficiency from Appendix F

HDEMhr = Heating Duct Efficiency Multiplier for the hour calculated according to Appendix P

The ACM shall calculate the hourly net heating load using Equation 4.28.f

NetHload = (Hloadhr*HDEMhr)/(HDE)   Eqn 4.28.f

4.28.1 Furnaces

Inputs:

$AFUE_{Eff}$ = Rated Seasonal Energy Efficiency from 4.18

The ACM shall calculate the hourly heating electricity consumption in Btu using Equation 4.28.f

FurnFuel = NetLoad/$AFUE_{Eff}$ Eqn 4.28.g

4.28.2 Heat pump and Electric Furnace

Inputs:

HSPF = Rated Heating Seasonal Performance Factor

EIR47 = defaults to 1/(0.4*HSPF)

Cap47 = Rated compressor heating capacity at 47 F. Defaults to rated cooling capacity.

If the heat pump compressor is not large enough to meet the load in the hour, the ACM assumes there is sufficient backup resistance heat. IN the case of an electric furnace, the load shall be met entirely by resistance heat. For heat pumps, the ACM shall calculate the hourly heating electricity consumption in kWh using the DOE2.1E heat pump algorithm.[21]

[21] Doe2 Engineers manual reference.

5. Minimum Capabilities Tests

This section describes the methods used to test the minimum modeling capabilities of candidate ACMs. There are three sets of tests: space conditioning tests, water heating tests and standard design generator tests. The space conditioning tests are performed using a simple square building prototype. The water heating tests are performed relative to several prototype water heating systems. The standard design generator tests use a single prototype building designed to have a wide variety of features. Most of the tests are performed in only five climate zones, but some require consideration in all sixteen climate zones.

Note: Except for tests 39 through 42, the minimum capabilities tests and optional capability tests do not include the SSEER adjustment added as part of the 2000 update as described in Chapter 3. This enables the runs used for the 1998 standards to be reused in this document. This requires that ACMs be programmed with some type of switch to allow the SEER ($SEER_{temperature}$) to be set to the input SEER, and the installation ($F_{install}$) and TXV (F_{txv}) factors to be set to 1.0 for these tests. This feature may not be used for compliance runs and should not be accessible by compliance users.

5.1 Prototype Building

The prototype buildings are illustrated below and described in the following paragraphs. Each is presented in much greater detail on diskettes available from the California Energy Commission[22]. Letter designations are used for the prototype buildings. The letter is used as part of the label for each computer run.

A This prototype is a square box used for most of the space conditioning tests.

B The second prototype building is identical to the first except that it has raised floor construction, instead of a slab-on-grade.

C This prototype is a 3,534 ft^2, one and two-story, single-family detached custom home.

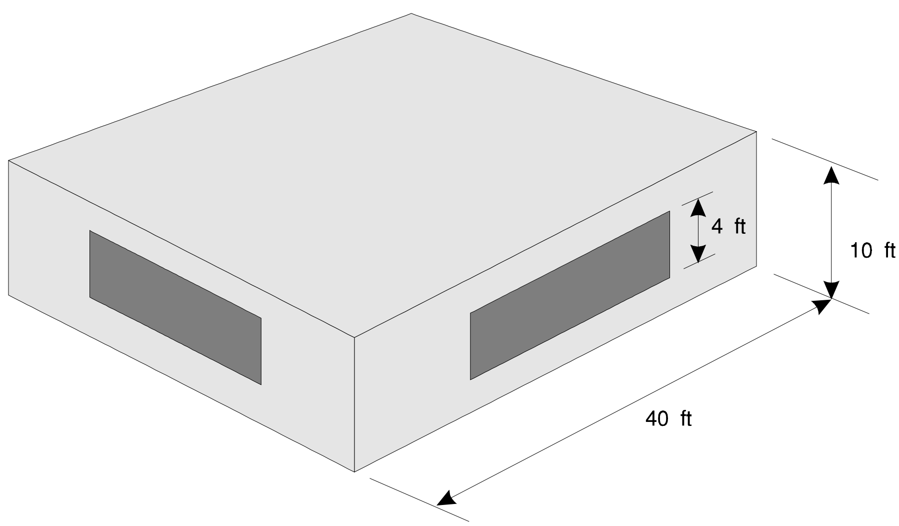


Figure 5-1 - Prototype Buildings A and B

[22] Write to ACM TEST FILES, California Energy Commission, 1516 Ninth St., MS#25, Sacramento, CA 95814-5512 to obtain copies of these input files on 3.5 inch, 1.44 Mbyte diskettes.

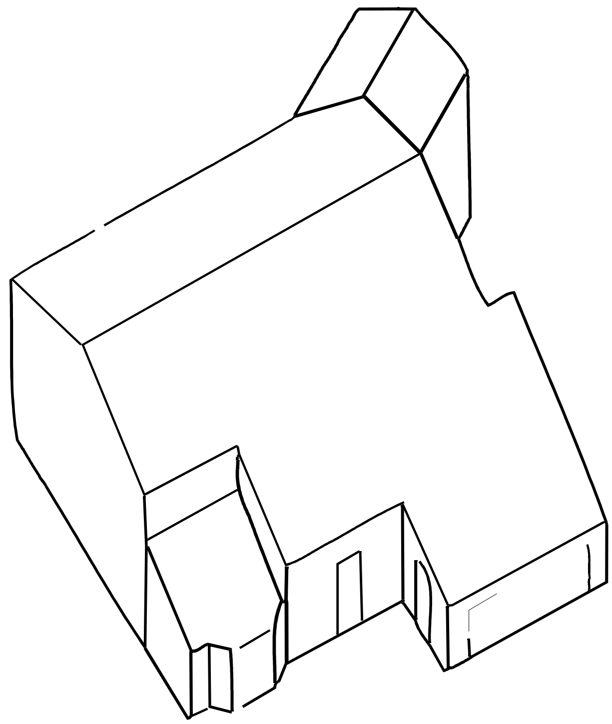


Figure 5-2 - Prototype C

Prototype buildings A and B have the same conservation features in all climate zones (see Table R5-1 below). The specific values associated with each of the basecase conservation measures is also summarized in the CALRES input files available from the Commission (see footnote 1 for this Chapter).

Table R5-1 - Basecase Conditions for Prototypes A and B

Component	Basecase Level	Notes
Roof U-value	0.034	
Wall U-value	0.088	
Floor U-value	0.037	
Slab F2 factor	0.76	4
Door U-value	0.330	
Thermal Mass	Slab 20% exposed, 80% covered	3
SHGC (exterior device) - (bugscreen)	0.76	
SHGC (interior)	0.68	
SHGC (fenestration - includes framing)	0.70	
Window type	Sliders	5
Fenestration U-Value	0.75	
Gas furnace AFUE	0.78	1
Air conditioner SEER	10.0	
HVAC ducts	R-4.2 Ducts in Attic	2
SLA	4.9	6

Notes:	
1	The AFUE(eff) is 0.7629 when the heat contribution and energy use of the fan is considered.
2	Duct efficiencies are as described for the standard design in Chapter 3 using the default values for an air conditioner with 36,000 Btu/hr cooling capacity.
3	Prototype B has thermal mass equivalent to 5% of the raised floor area in 2 inch thick exposed concrete per Section 3.6..
4	Assumes 80% of the slab at building perimeter is carpeted or covered.
5	The default natural ventilation assumptions are used. 10% of the window area is operable (half of this is inlet and half is outlet). Height difference between inlet and outlet is 2 feet.
6	Based on having ducts in unconditioned attic space.

The computer runs used to generate the ACM tests are based on the standard modeling assumptions described in Chapter 4. Copies of these computer runs are available to assist candidate ACMs in setting their programs up for CEC approval. These input files may be obtained by writing the Residential Buildings Office, California Energy Commission, 1516 Ninth Street (MS-25), Sacramento, California 95814.

5.2 Labeling Computer Runs

Each computer run used to test the minimum space conditioning capabilities is given a precise designation to make it easier to keep track of the runs and to facilitate analysis. The following scheme is used:

12 A 04

Variation on the basecase building used to test minimum space conditioning capabilities (usually the same as the test number)

Prototype A

Climate zone 12

5.2.1 Basecase Runs

The first series of runs establish the basecase against which the other runs are compared. The variation number for the basecase run is "00". The basecase energy use is calculated for prototype A in all sixteen climate zones. The energy usage for the other prototypes is calculated only for climate zones 3, 9, 12, 14 and 16. It is important to note that only two input files are required for these computer runs since measures do not change from climate zone to climate zone. The label for these tests are shown in the table below. Total of 21 Runs.

Table R5-2- Basecase Run Labels

	Building Prototype		
Climate Zone	**A**	**B**	
1	01A00	_	
2	02A00	_	
3	03A00	03B00	
4	04A00	_	
5	05A00	_	
6	06A00	_	
7	07A00	_	
8	08A00	_	
9	09A00	09B00	
10	10A00	_	
11	11A00	_	
12	12A00	12B00	
13	13A00	_	
14	14A00	14B00	
15	15A00	_	
16	16A00	00B16	

Test One

The purpose of the first test is to check the prediction of the ACM for relative heating and cooling loads. The heating efficiency is increased and the cooling equipment efficiency is decreased. When the changes in heating and cooling efficiency are made, additional energy use must result. *Total of 19 Runs.*

Table R5-3- Test One Inputs

Run Label	New Heating Efficiency	New Cooling Efficiency
02A01	0.85	8.0
03A01	0.85	5.5
04A01	0.85	7.0
05A01	0.85	5.5
06A01	0.95	6.5
07A01	0.95	7.0
08A01	0.95	7.5
09A01	0.95	8.0
10A01	0.95	8.5
11A01	0.95	8.1
12A01	0.95	7.8
13A01	0.95	8.8
14A01	0.95	8.4
16A01	0.85	5.5
03B01	0.85	6.0
09B01	0.95	8.8
12B01	0.95	7.5
14B01	0.95	8.2
16B01	0.85	5.8

Test Two

Test two is similar to test one except that the cooling efficiency is increased and the heating efficiency is decreased, just the opposite of test one. When the changes in heating and cooling efficiency are made, additional energy use must result. *Total of 19 Runs.*

Table R5-4- Test Two Inputs

Run Label	New Heating Efficiency	New Cooling Efficiency
02A02	0.65	12.5
03A02	0.72	12.5
04A02	0.66	12.5
05A02	0.65	12.5
06A02	0.55	12.5
07A02	0.50	12.5
08A02	0.49	12.5
09A02	0.45	12.5
10A02	0.45	12.5
11A02	0.63	12.5
12A02	0.62	12.5
13A02	0.52	12.5
14A02	0.57	12.5
16A02	0.75	12.5
03B02	0.70	12.5
09B02	0.46	12.5
12B02	0.61	12.5
14B02	0.59	12.5
16B02	0.74	12.5

Test Three

Test three is performed only for prototype A in five climate zones, 3, 9, 12, 14 and 16. The ceiling U-value is reduced to 0.023 from the basecase of 0.033. The south glass area is increased a specific amount for each climate zone. Each of these computer runs must result in greater energy use than the prototype A basecase. *Total of five runs.*

Table R5-5 - Test Three Inputs

Run Label	Roof U-value	South Glass Area
03A03	0.023	200
09A03	0.023	120
12A03	0.023	140
14A03	0.023	160
16A03	0.023	160

Test Four

Test four is performed only for prototype A in five climate zones, 3, 9, 12, 14 and 16. The wall U-value is reduced to 0.060 from the basecase of 0.088. The west glass area is increased a specific amount for each climate zone. Each of these computer runs must result in greater energy use than prototype A. *Total of five runs.*

Table R5-6 - Test Four Inputs

Run Label	Wall U-value	West Glass Area
03A04	0.060	170
09A04	0.060	130
12A04	0.060	119
14A04	0.060	121
16A04	0.060	150

Test Five

Test five is performed only for prototype A in five climate zones, 3, 9, 12, 14 and 16. R-7 slab edge insulation is added, i.e. an F2 factor of 0.65 is used instead of the 0.76 used in the basecase. The north glass area is increased a specific amount for each climate zone. Each of these computer runs must result in greater energy use than prototype A. *Total of five runs.*

Table R5-7 - Test Five Inputs

Run Label	F2 Factor	North Glass Area
03A05	0.51	220.5
09A05	0.51	150
12A05	0.51	170
14A05	0.51	160
16A05	0.51	180

Test Six

Test six is performed only for prototype A in four climate zones: 9, 12, 14 and 16. The glazing U-value is changed to 0.54 instead of the 0.75 used in the basecase. The north glass area is increased a specific amount for each climate zone. Each of these computer runs must result in greater energy use than prototype A. *Total of four runs.*

Table R5-8 - Test Six Inputs

Run Label	Glazing U-value	North Glass Area
09A06	0.54	192
12A06	0.54	286
14A06	0.54	269
16A06	0.54	300

Test Seven

Test seven is performed only for prototype A in five climate zones: 3, 9, 12, 14 and 16. The fenestration U-value is increased to 1.28 (single glass) from the basecase 0.75 (mild climate zone standard). The solar heat gain coefficients for the window are also changed to account for the single glass ($SHGC_{fen}$ = 0.80). The glass area is reduced uniformly on all orientations. Ventilation area also varies with glass area, remaining at 10% of the total area. Each of these computer runs must result in greater energy use than prototype A. *Total of five runs*

Table R5-9 - Test Seven Inputs

Run Label	Glass U-value	$SHGC_{fen}$	Glass Area on Each Orientation
03A07	1.28	0.80	55
09A07	1.28	0.80	71
12A07	1.28	0.80	65
14A07	1.28	0.80	63
16A07	1.28	0.80	51

Test Eight

Test eight is performed only for prototype A in five climate zones: 3, 9, 12, 14 and 16. The percent of the slab-on grade that is exposed thermal mass is increased: 500 ft^2 is exposed and 1100 ft^2 is carpeted. The slab edge heat loss, however, is unaffected; the F2 factor remains at 0.76. The south glass area is increased a specific amount for each climate zone. Each of these computer runs must result in greater energy use than prototype A. *Total of five runs.*

Table R5-10 - Test Eight Inputs

Run Label	Exposed Mass	South Glass Area
03A08	31.25%	195
09A08	31.25%	128
12A08	31.25%	131
14A08	31.25%	160
16A08	31.25%	128

Test Nine

Test nine is identical to test eight except west glass area is increased. This test is performed only for prototype A in five climate zones: 3, 9, 12, 14, and 16. Each of these computer runs must result in greater energy use than prototype A. *Total of five runs.*

Table R5-11 - Test Nine Results

Run Label	Exposed Mass	West Glass Area
03A09	31.25%	158
09A09	31.25%	131
12A09	31.25%	118
14A09	31.25%	113
16A09	31.25%	128

Test Ten

Test ten is identical to test eight except north glass area is increased. This test is performed only for prototype A in five climate zones: 3, 9, 12, 14 and 16. Each of these computer runs must result in greater energy use than prototype A. *Total of five runs.*

Table R5-12 - Test Ten Results

Run Label	Exposed Mass	North Glass Area
03A10	31.25%	152
09A10	31.25%	199
12A10	31.25%	141
14A10	31.25%	126
16A10	31.25%	112

Test Eleven

Test eleven is identical to test eight except east glass area is increased. This test is performed only for prototype A in five climate zones: 3, 9, 12, 14 and 16. Each of these computer runs must result in greater energy use than the prototype A basecase. *Total of five runs.*

Table R5-13 - Test Eleven Results

Run Label	Exposed Mass	East Glass Area
03A11	31.25%	184
09A11	31.25%	150
12A11	31.25%	127
14A11	31.25%	117
16A11	31.25%	119

Test Twelve

Test twelve is performed only for prototype A in five climate zones, 3, 9, 12, 14 and 16. The floor is changed from a slab-on-grade floor to a raised wooden floor over a crawl space with an overall U-value of 0.037. Exterior shading devices are used in other climate zones 9, 12 and 14 on all windows, to achieve the $SHGC_{fen}$ values indicated below. Glass area on the west facade is increased a specific amount for each climate zone. Each of these computer runs must result in greater energy use than prototype A. *Total of five runs.*

Table R5-14 - Test Twelve Inputs

Run Label	Raised Floor - U-value	$SHGC_{fen}$	West Glass Area
03A12	0.037	0.80	64
09A12	0.037	0.40	180
12A12	0.037	0.40	125
14A12	0.037	0.40	140
16A12	0.037	0.80	120

Test Thirteen

In test thirteen, an interior shading device is used on all windows which has a solar heat gain coefficient of 0.47 when the device is used with single pane, metal-framed fenestration ($SHGC_{fen}$ = 0.80) and is closed. The area of south glass is increased a specific amount for each climate zone. This test is performed for the prototype A building in five climates. Each of these computer runs must result in greater energy use than the prototype A basecase. *Total of five runs.*

Table R5-15 - Test Thirteen Inputs

Run Label	SHGC Interior Shade	South Glass Area
03A13	0.47	200
09A13	0.47	200
12A13	0.47	222
14A13	0.47	244
16A13	0.47	160

Test Fourteen

Test fourteen evaluates how the ACM treats south overhangs. It is performed for the prototype A building in five climate zones: 3, 9, 12, 14 and 16. In each case a south overhang is added to the building. The overhang has a two foot projection from the surface of the south glass. Its bottom edge is located six inches above the top of the window. It is assumed that the south glazing consists of six-foot six-inch high windows. The overhang is assumed to extend an infinite distance beyond the sides of the windows. The overhang characteristics are illustrated below. South glazing area is then increased by increasing its width. Each case must result in greater energy use than prototype A. *Total of five runs.*

Table R5-16 - Test Fourteen Inputs

Run Label	South Overhang	South Glass Area
03A14	yes	169
09A14	yes	132
12A14	yes	144
14A14	yes	129
16A14	yes	100

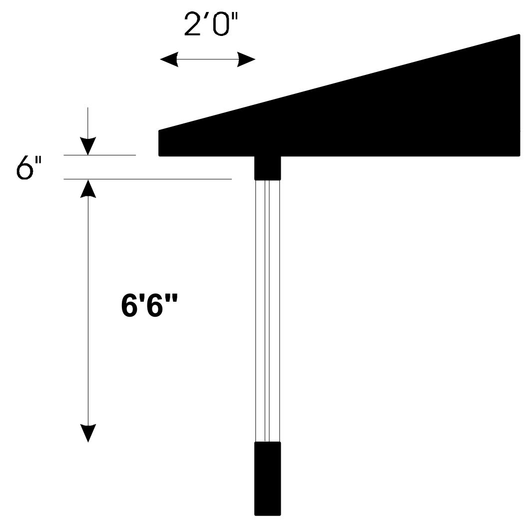


Figure 5-3 - Overhang Characteristics

Test Fifteen

This test is for the infiltration and ventilation model. It is performed for the prototype A building in five climate zones: 3, 9, 12, 14 and 16. The basecase building has ducts in unconditioned space, therefore, the fixed and restricted inputs specify a SLA of 4.9. In this test building leakage is reduced to an SLA of 2.9 by infiltration reduction measures and is modeled with and without 80 cfm (0.375 air changes per hour) of mechanical ventilation which consumes 20 watts of power continuously. Glass area is increased on all orientations so that the building fails to comply. *Total of ten runs*.

Table R5-17 - Test Fifteen Inputs

Run Label	Specific Leakage Area	Fan Volume & Wattage	Maximum Glass Area on Each Orientation A/B
03A15A	2.90	0 cfm/0 watts	131
03A15B	2.90	80 cfm/20 watts	110
09A15A	2.90	0 cfm/0 watts	100
09A15B	2.90	80 cfm/20 watts	96
12A15A	2.90	0 cfm/0 watts	100
12A15B	2.90	80 cfm/20 watts	80
14A15A	2.90	0 cfm/0 watts	100
14A15B	2.90	80 cfm/20 watts	80
16A15A	2.90	0 cfm/0 watts	100
16A15B	2.90	80 cfm/20 watts	72

5.3 Water Heating Tests

Testing of ACM minimum capabilities for water heating is completely separate from the space conditioning tests. One of the principal differences between water heating and space conditioning is that fixed energy budgets are used for water heating rather than custom budgets. The testing procedures are, therefore, fundamentally different. Candidate ACMs must exactly replicate the results of the official CEC water heating methodology for various system types.

5.3.1 Prototype Water Heaters

There are seven water heaters that are used for the tests. These systems are labeled E, F, G, and J. Detailed specifications for each water heating system are given in Table R5-18 - Water Heating Systems below. The energy use of each of the water heating systems is calculated with several distribution systems.

Table R5-18 - Water Heating Systems

		E	**F**	**G**	**J**
System Level Information					
Climate Zone		3	7	16	5
Dwelling Units		10	1	1	3
Average Dwelling Unit Size		1200	1500	3500	800
Number of Water Heaters		5	1	2	6
Water Heating Equipment					
Water Heater Type		LG	HP	HP	IE
Energy Factor (Note 1)		0.77	2.00	1.80	0.95
Tank Size	Gal	100	50	75	na.
Standby Loss	%	3%.	n.a.	n.a.	n.a.
Input Rating	kBtu/h	100	n.a.	n.a.	n.a.
Notes 1. For instantaneous gas (IG) and large gas (LG) water heaters the value reported in this row is the recovery efficiency or thermal efficiency.					

5.3.2 Labeling Computer Runs

Each water heating calculation is given a precise designation to make it easier to keep track of the runs and to facilitate analysis. The following scheme is used:

12 F POU

Distribution system type

Prototype water heater system F

Climate zone 12

5.3.3 Test Results

Water heater types E, F, G, and J are analyzed in just one climate zone (except for heat pumps, the results should not change by climate zone). The results must exactly replicate the values shown in the following tables. A summary sheet is provided in Appendix A that must be completed by the vendor. *Total of 40 calculations.*

Table R5-19 - Water Heater Results (kBtu/yr)

		E	F	G	J
Energy Budget		221.900	23.645	28.495	60.750
Distribution System	DSM				
Standard	1	218.208	18.064	45.731	85.085
POU/HWR	0.82	na	15.875	43.940	na
Pipe Insulation	0.92	207.304	17.100	47.178	78.278
Recirc/NoControl	1.52	289.082	24.080	65.630	129.329
Recirc/Timer	1.28	na	21.345	58.427	na
Recirc/Demand	0.98	na	17.824	49.096	na
Recirc/Time+Temp	0.96	na	17.583	48.459	na
Recirc/Temp	1.05	225.023	18.660	51.310	89.339
Parallel Piping	0.86	199.126	16.367	45.242	73.123

5.4 Standard Design Generator Tests

The standard design generator must automatically define the standard design which is the basis of the custom budget. The standard design run is made automatically at the same time as the proposed design run, and the results are reported together on the Computer Method Summary discussed in Chapter 2. This test verifies that the standard design is correctly defined for the proposed design and that the custom budget is correctly calculated.

The standard design test consists of matched pairs of computer runs: a proposed design and its standard design equivalent. The standard design equivalent is the proposed design reconfigured according to the standard design rules in Chapter 3.

Two Computer Method Summaries are produced: one for the proposed design and one for the standard design equivalent. The standard design energy budget on the proposed design Computer Method Summary must be equal to the energy use shown in both the standard design energy budget and proposed design columns of the standard design equivalent computer run.

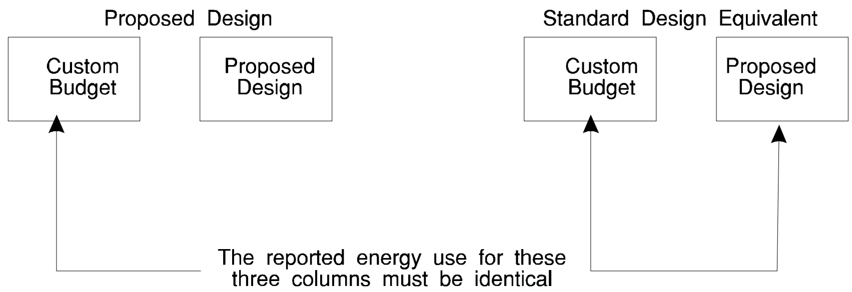


Figure 5-4 - Custom Budget Tests

5.4.1 Slab Floor Test

The purpose of this test is to verify that the standard design generator correctly defines the standard design for proposed designs using slab-on-grade designs. Package D is now the basis of the standard design for all buildings including slab-on-grade buildings. The rules for determining how much thermal mass is modeled in buildings with both raised and slab-on-grade construction are contained in Chapters 3 and 4. The prototype C variation used for this test has both raised floors and slab-on-grade floors.

Prototype "xxC31" is run in all sixteen climate zones, and the standard design equivalent in each climate zone is also run. The results must be exactly identical as discussed above. The labels for this series of runs are summarized in the following table. *Total of 32 runs.*

Table R5-20 - Slab Floor Standard Design Tests

Climate Zone	Proposed Design	Standard Design Equivalent
1	01C31	01C31C
2	02C31	02C31C
3	03C31	03C31C
4	04C31	04C31C
5	05C31	05C31C
6	06C31	06C31C
7	07C31	07C31C
8	08C31	08C31C
9	09C31	09C31C
10	10C31	10C31C
11	11C31	11C31C
12	12C31	12C31C
13	13C31	13C31C
14	14C31	14C31C
15	15C31	15C31C
16	16C31	16C31C

5.4.2 Raised Floor Test

The purpose of this test is to verify that the standard design generator correctly defines the standard design for a proposed design for a dwelling with a raised floor. This is a parallel test to the previous one except that a modification of the prototype building is used which is the prototype C building with no slab floor but with 5% of the nonslab floor covered with 2 inches of exposed concrete. This modification is labeled "xxC32" and is contained in Appendix C in the standard format of the Computer Method Summary.

The modified prototype C building is run in all sixteen climate zones, and the standard design equivalent in each climate zone is also run. The results must be exactly identical. The labels for this series of runs are summarized in the following table. *Total of 32 runs.*

Table R5-21 - Raised Floor Standard Design Tests

Climate Zone	Proposed Design	Standard Design Equivalent
1	01C32	01C32C
2	02C32	02C32C
3	03C32	03C32C
4	04C32	04C32C
5	05C32	05C32C
6	06C32	06C32C
7	07C32	07C32C
8	08C32	08C32C
9	09C32	09C32C
10	10C32	10C32C
11	11C32	11C32C
12	12C32	12C32C
13	13C32	13C32C
14	14C32	14C32C
15	15C32	15C32C
16	16C32	16C32C

5.4.3 Electric Heat Test

The purpose of this test is to verify that the standard design generator correctly defines the standard design for proposed designs with electric heating systems. This a parallel test to the previous custom budget tests, except that a modification of the prototype building is used. This modification is labeled "xxC33" and is contained in Appendix C in the standard format of the Computer Method Summary.

The modified prototype C building with electric resistance heating is run in all sixteen climate zones, and the standard design equivalent which uses an electric heat pump with an HSPF of 6.8 in each climate zone is also run. The results for the *Standard Designs* for both runs and the *Proposed Design* for the *Standard Design* equivalent must be exactly identical. The labels for this series of runs are summarized in the following table. *Total of 32 runs.*

Table R5-22 - Electric Heat Standard Design Tests

Climate Zone	Proposed Design	Standard Design Equivalent
1	01C33	01C33C
2	02C33	02C33C
3	03C33	03C33C
4	04C33	04C33C
5	05C33	05C33C
6	06C33	06C33C
7	07C33	07C33C
8	08C33	08C33C
9	09C33	09C33C
10	10C33	10C33C
11	11C33	11C33C
12	12C33	12C33C
13	13C33	13C33C
14	14C33	14C33C
15	15C33	15C33C
16	16C33	16C33C

5.4.4 HVAC Distribution Efficiency Tests

The Standard Design uses the defaults of the HVAC distribution efficiency calculation method found in Appendix F to determine the HVAC distribution efficiency. These defaults result in seasonal HVAC distribution efficiencies of about 72-76% depending on the climate zone. The calculation method detailed in Appendix F gives efficiency credits for certain specific improvements in the HVAC distribution system, such as, higher duct insulation levels, careful duct design and layout, and reduced duct leakage due to better sealing techniques. HVAC distribution efficiency improvements must be independently verified and some are subject to site diagnostic testing by a certified HERS rater.

For these tests prototype building A is used. For the first series of tests, the ducts are designed to conform to ACCA Manual D specifications with room-by-room load calculations and have a duct layout design on the plans. The ducts are sealed and tested. The results must replicate the values shown in the following table.

Table R5-23 - Duct Efficiency Tests

Run Label	Standard Heating Duct Efficiency	Standard Cooling Duct Efficiency	ACCA Manual D Design	Tested Duct Leakage	Heating Duct Efficiency	Cooling Duct Efficiency
03A34	0.759	0.730	Yes	Yes	0.827	0.850
09A34	0.753	0.702	Yes	Yes	0.822	0.838
12A34	0.743	0.674	Yes	Yes	0.815	0.817
14A34	0.709	0.617	Yes	Yes	0.789	0.775
16A34	0.686	0.730	Yes	Yes	0.773	0.850
03A35	0.759	0.730	No	Yes	0.827	0.786
09A35	0.753	0.702	No	Yes	0.822	0.775
12A35	0.743	0.674	No	Yes	0.815	0.756
14A35	0.709	0.617	No	Yes	0.789	0.717
16A35	0.686	0.730	No	Yes	0.773	0.786

For the second series of tests, duct location is run for six tests with 10 lineal feet of ducts and the air handler are in an unconditioned garage and the remainder of the ducts are in conditioned space. The tests are rerun with all of the ducts and the air handler in the conditioned space. For all of the tests in this series, ducts are sealed and tested. The results must replicate the values shown in the following table.

Table R5-24 – Duct Efficiency Tests

Run Label	Standard Heating Duct Efficiency	Standard Cooling Duct Efficiency	Duct Location	Tested Duct Leakage	Heating Duct Efficiency	Cooling Duct Efficiency
03A36	0.759	0.730	Cond./InEx12	Yes	0.920	0.860
09A36	0.753	0.702	Cond./InEx12	Yes	0.917	0.846
12A36	0.743	0.674	Cond./IInEx12	Yes	0.914	0.836
14A36	0.709	0.617	Cond./IInEx12	Yes	0.902	0.815
16A36	0.686	0.730	Cond./IInEx12	Yes	0.894	0.860

The ACM or its research version must report the duct efficiencies for the HVAC distribution efficiency tests.

5.4.5 Addition Plus Existing Building Test

Additions are treated as new buildings except that internal heat gains are allocated on a fractional dwelling unit basis. When an addition is modeled in conjunction with an existing building, energy credit may be taken for improvements to the existing building. This series of tests exercises the various default assumptions based on the vintage of the existing building and the various reporting requirements for modeling an addition with an existing building. In addition, these tests verify the proper determination of the energy budget and compliance criteria for an addition with an improved existing building.

For these tests the existing building has the same physical configuration as Prototype A but has single pane, metal-framed windows on all four sides with a window on each vertical elevation that is 4’ high and 20’ wide centered on the facade. The 12’ deep by 40’ long addition covers the whole west side of the existing building. The addition faces west and has west-facing glazing with a U-value of 0.75 and an $SHGC_{fen}$ of 0.70. The addition covers 80 ft^2 of existing glass. For test series 37, the mandatory minimum R-values are used in the addition’s roof/ceiling and walls. Hence for test series 37, the U-value for the roof/ceiling of the addition is 0.047 corresponding to R-19 insulation and the wall U-value is 0.088 corresponding to R-13 wall insulation.

For test series 38, the existing building's roof and the addition roof insulation is brought up to the requirements for a new dwelling. The addition's west-facing glazing is increased until the building no longer complies with the budget determined from modeling the existing building and modeling the addition and area weighting the heating and cooling budgets for those runs.

These tests will also be used to confirm that output requirements are met when modeling an addition with an existing building and that the appropriate budgets have been correctly determined.

Table R5-25- Additions Tests Inputs

Run Label	Vintage of Existing Building	$SHGC_{fen}$	Covered Existing Glazing	U-Value of Roof/Ceiling Existing/Add.	West-Facing Glazing for the Addition (ft^2)
03D37	1977	0.70	80 ft^2	0.077/0.047	380
09D37	1977	0.70	80 ft^2	0.077/0.047	270
12D37	1977	0.70	80 ft^2	0.077/0.047	320.
14D37	1977	0.70	80 ft^2	0.077/0.047	360
16D37	1977	0.70	80 ft^2	0.077/0.047	370
03D38	1989	0.70	80 ft^2	0.034/0.034	20
09D38	1989	0.70	80 ft^2	0.034/0.0-34	100
12D38	1989	0.70	80 ft^2	0.034/0.034	80
14D38	1989	0.70	80 ft^2	0.028/0.028	80
16D38	1989	0.70	80 ft^2	0.028/0.028	8

5.4.6 Cooling System SSEER Tests

Calculation of the source SEER (SSEER) for air conditioners is described in Chapter 3. To test this calculation, a series of different air conditioner configurations are modeled using prototype building A. The $SSEER_{prototype}$ parameters assume a split system air conditioner, 10 SEER, with duct sealing. Duct design is not used and TXVs are included in climate zones 9, 12 and 14. Ducts are located in the attic with R4.2 insulation for all tests. Four separate $SSEER_{test}$ configurations are used as specified in the following table. The results must replicate the values shown in the following table.

Table R5-26 – SSEER Tests

Run Label	SSEER prototype	System Type	SEER	TXV	Duct Sealing	ACCA Manual D Duct Design	SSEER test
03A39	6.528	SplitAirCond	12	Yes	Yes	Yes	8.977
09A39	6.899	SplitAirCond	12	Yes	Yes	Yes	8.435
12A39	6.591	SplitAirCond	12	Yes	Yes	Yes	8.001
14A39	6.003	SplitAirCond	12	Yes	Yes	Yes	7.182
16A39	6.495	SplitAirCond	12	Yes	Yes	Yes	8.915
03A40	6.528	SplitAirCond	10.5	Yes	No	No	7.068
09A40	6.899	SplitAirCond	10.5	Yes	No	No	6.553
12A40	6.591	SplitAirCond	10.5	Yes	No	No	6.161
14A40	6.003	SplitAirCond	10.5	Yes	No	No	5.413
16A40	6.495	SplitAirCond	10.5	Yes	No	No	7.026
03A41	6.528	SplitAirCond	19	No	No	No	10.004
09A41	6.899	SplitAirCond	19	No	No	No	8.207
12A41	6.591	SplitAirCond	19	No	No	No	7.210
14A41	6.003	SplitAirCond	19	No	No	No	5.563
16A41	6.495	SplitAirCond	19	No	No	No	9.823
03A42	6.528	PkgAirCond	11.7	No	Yes	Yes	8.201
09A42	6.899	PkgAirCond	11.7	No	Yes	Yes	7.731
12A42	6.591	PkgAirCond	11.7	No	Yes	Yes	7.348
14A42	6.003	PkgAirCond	11.7	No	Yes	Yes	6.621
16A42	6.495	PkgAirCond	11.7	No	Yes	Yes	8.145

6. Optional Capabilities Tests

This section of the Manual explains the tests that must be performed in order for residential ACMs to be approved for optional capabilities. Most of the tests are performed relative to one of the prototype buildings identified in the previous section. Each computer run used to test the minimum space conditioning capabilities is given a precise designation to make it easier to keep track of the runs and to facilitate analysis. Optional capabilities tests begin with the test number "51". The following scheme is used:

12 E 51

Optional capabilities test four

Prototype A is used as the basis of the test

Climate zone 12

6.1 Controlled Ventilation Crawl Spaces (CVC)

Controlled ventilation crawl spaces is an optional capability based on the ability of an ACM to model more than one thermal zone. The crawl space of the building is modeled as a separate, unconditioned thermal zone. Details of the test model are provided in Appendix C, test file 12B51. Some key features are summarized below.

The CVC zone has an exterior perimeter length and floor area (i.e., the ground area) equal to the prototype building B perimeter and floor area. Crawlspace volume is 3467 ft^3. CVC infiltration is modeled using the air changes per hour method and uses 0.22 air changes per hour.

The floor separating the crawl space from conditioned space becomes an interzone boundary. 400 ft2 of this floor has a U-value of 0.342, representing an uninsulated, uncarpeted floor, and the remainder has a U-value of 0.199, representing an uninsulated, carpeted floor.

Insulation is placed in the perimeter walls of the crawl space, and the crawl space vents are modeled with automatic seasonally operated louvers to minimize ambient conditions within the crawl space. When the building is in a heating mode, the vents are closed (inlet and outlet are zero). When the building is in a cooling mode, the vents are open and the total vent area is 1/150 of the crawlspace floor area or 10.67 ft2. Half of this is inlet and half outlet. The ventilation height difference is zero. Only wind effects apply. Wind speed is reduced to 25% of that on the weather tape to account for ground level conditions. Heat capacity in the crawlspace is 1.4 Btu/F-ft2.

When insulation is placed in the perimeter walls of the crawl space in lieu of the floor assembly, other requirements are triggered for builders. The definition of "controlled ventilation crawlspace", in the glossary of the *Residential Manual*, should be consulted for more details.

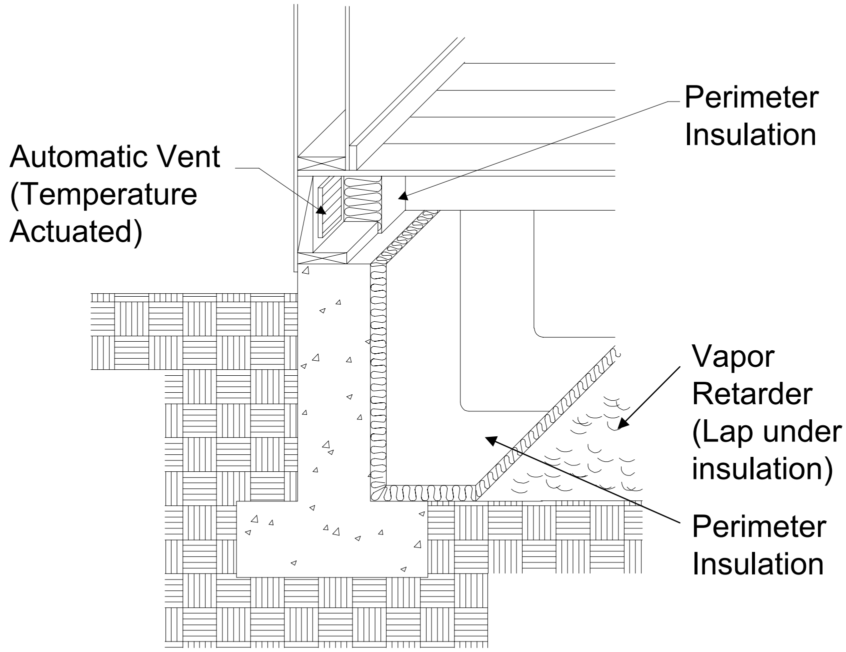


Figure 6-1 - Section at Crawlspace Perimeter

CVC is tested only for prototype building B in five climate zones: 3, 9, 12, 14 and 16. CVC is added and the heating efficiency is modified accordingly. Each computer run must result in greater energy use than the prototype B basecase building. The computer runs are summarized below. *Total of five runs.*

Table R6-1 - Controlled Ventilation Crawlspace Test Inputs

Run Label	CVC	Heating AFUE
03B51	yes	0.63
09B51	yes	0.43
12B51	yes	0.64
14B51	yes	0.69
16B51	yes	0.74

The optional capability test also requires that the vendor demonstrate that the ACM correctly defines the standard design building and calculates the custom budget. This test involves running the standard design equivalent building for climate zone 12 and showing that the custom budget figures from computer run "12B51" are equal. The standard design equivalent building is included in Appendix C and labeled "12B51C".

6.2 Zonal Control

Zonal control is one of the optional capabilities based on the ability of an ACM to model more than one thermal zone at the same time. With zonal control, the sleeping and living areas are modeled separately, each with its own separate thermostat schedule and internal gain assumptions. The specifications for the building with zonal control are detailed in CALRES input test file 12A52 available from the Commission on diskette. Further discussion is provided in the Residential Manual, in Section 8.9, and in the glossary under "zonal control". Key features are discussed below.

6.2.1 Prototype Zones

Figure 6-2 depicts the prototype building separated into living and sleeping zones. The boundary between the zones consists of a wall with U-value of 0.29 and net area of 360 square feet. The wall contains an uncloseable opening of 40 square feet, modeled with a U-value of 20.0.

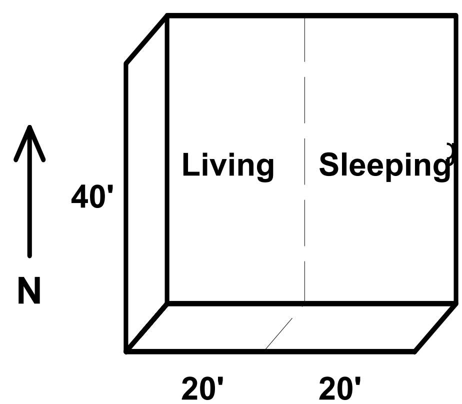


Figure 6-2 - Zoning the Prototype Building

6.2.2 Thermostats

The thermostat schedule for the living area is the same as the standard assumptions except that the cooling setpoint is 83°F between 11:00 pm and 7:00 am.

The thermostat schedule for the sleeping area has two heating setback periods: between 11:00 pm and 7:00 am and between 8:00 am and 9:00 pm. The cooling thermostat has one setup period to 83°F, between 8:00 am and 9:00 pm. The thermostat schedules for zonal control are shown in Table R6-2 - Zonal Control Thermostat Set Points below.

Table R6-2 - Zonal Control Thermostat Set Points

Hour	Heating	Cooling	Hour	Heating	Cooling	Hour	Heating	Cooling
Living Areas								
1	60	83	9	68	78	17	68	78
2	60	83	10	68	78	18	68	78
3	60	83	11	68	78	19	68	78
4	60	83	12	68	78	20	68	78
5	60	83	13	68	78	21	68	78
6	60	83	14	68	78	22	68	78
7	60	83	15	68	78	23	68	78
8	68	78	16	68	78	24	60	83
Sleeping Areas								
1	60	78	9	60	83	17	60	83
2	60	78	10	60	83	18	60	83
3	60	78	11	60	83	19	60	83
4	60	78	12	60	83	20	60	83
5	60	78	13	60	83	21	60	83
6	60	78	14	60	83	22	68	78
7	60	78	15	60	83	23	68	78
8	68	83	16	60	83	24	60	78

6.2.3 Internal Gains

Total internal gains are split between the living areas and the sleeping areas as indicated in the following equations.

Equation 6-1

$$\text{Int-Gain}_{\text{living}} = (20{,}000) + (15 \times \text{CFA}_{\text{living}})$$

Equation 6-2

$$\text{Int-Gain}_{\text{sleeping}} = 15 \times \text{CFA}_{\text{sleeping}}$$

An alternate set of internal gain schedules are used: one for the living areas of the house and one for the sleeping areas. These alternate schedules are shown in Table R6-3.

Table R6-3 - Internal Gain Schedules for Zonal Control

Hour	Percent	Hour	Percent	Hour	Percent
Living Areas					
1	1.61	9	6.33	17	6.19
2	1.48	10	6.86	18	7.18
3	1.14	11	6.38	19	7.24
4	1.13	12	5.00	20	5.96
5	1.21	13	4.84	21	5.49
6	1.46	14	3.15	22	6.20
7	2.77	15	2.94	23	4.38
8	5.30	16	3.41	24	2.35
Sleeping Areas					
1	4.38	9	3.76	17	4.47
2	4.02	10	3.85	18	4.45
3	4.50	11	4.70	19	4.29
4	4.50	12	3.61	20	3.30
5	4.32	13	3.65	21	3.75
6	5.46	14	2.63	22	3.75
7	6.39	15	2.46	23	4.45
8	7.40	16	2.32	24	3.59

6.2.4 Tests

The zonal control feature is tested only for prototype A in five climate zones: 3, 9, 12, 14 and 16. Zonal control is added and the heating efficiency is modified accordingly. Each computer run must result in greater energy use than prototype A. The computer runs are summarized in Table R6-4 below. *Total of five runs.*

Table R6-4 - Zonal Control Test Inputs

Run Label	Zonal Control	Heating AFUE
03A52	yes	0.74
09A52	yes	0.55
12A52	yes	0.68
14A52	yes	0.68
16A52	yes	0.73

The optional capability test also requires that the vendor demonstrate that the ACM correctly defines the standard design building and calculates the custom budget. This test involves running the standard design equivalent building for climate zone 12 and showing that the custom budget figures from computer run "12A52" are equal. The standard design equivalent building is included in Appendix C and labeled "12A52C".

6.3 Sunspaces

Sunspace modeling is one of the optional capabilities based on the ability of an ACM to model more than one thermal zone at the same time. The sunspace of the building is modeled as a separate, unconditioned thermal zone. The specifications for the test building are detailed in the CALRES input test file 12A53 available from the Commission on diskette, and key features are highlighted below.

An unconditioned sunspace is added to the south side of Prototype A as illustrated in Figure 6-3 and Figure 6-4. The wall and window separating the sunspace and the house remains the same as in the base case, but the surfaces and vent openings of this wall are changed from exterior types to interzone types. The interzone vent is controlled to open only when temperature (T) conditions are $T_{house} < T_{desired}$ and $T_{sunspace} > T_{house}$ (in heating mode).

The performance characteristics of sunspace envelope components are the same as for the basecase prototype, except slab F2-value is 0.90; fenestration shading coefficient is 0.90, no internal shading device is assumed. Total vent area is assumed to be 40 ft2 with an eight foot height difference

In the sunspace zone, assumptions for infiltration, heat capacity, solar gain targeting, and zone thermostat temperature settings vary from the conditioned zone. Sunspace zone infiltration is modeled using the air changes per hour method and the same infiltration factors as used in the 1988 ACM manual, 0.50 air changes per hour. There are no restrictions on targeting solar gains that enter unconditioned spaces such as sunspaces.

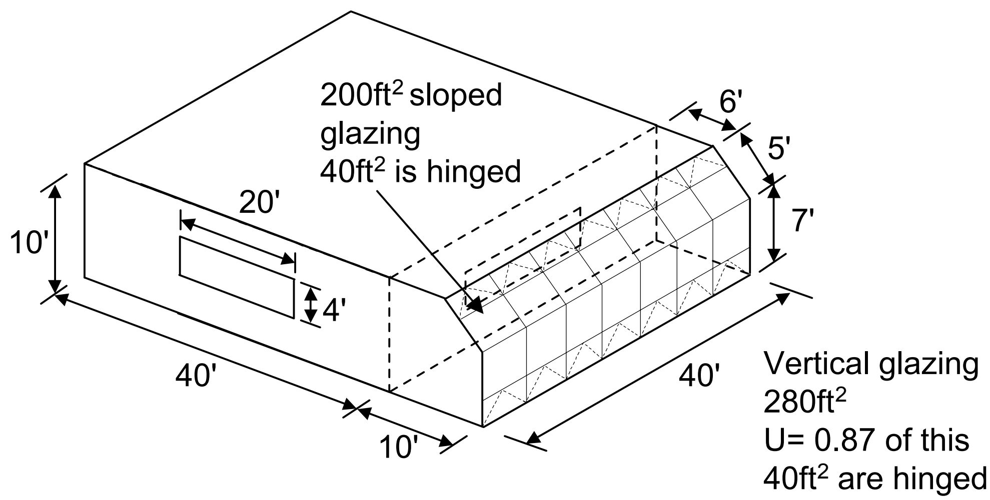


Figure 6-3 -- Sunspace Prototype

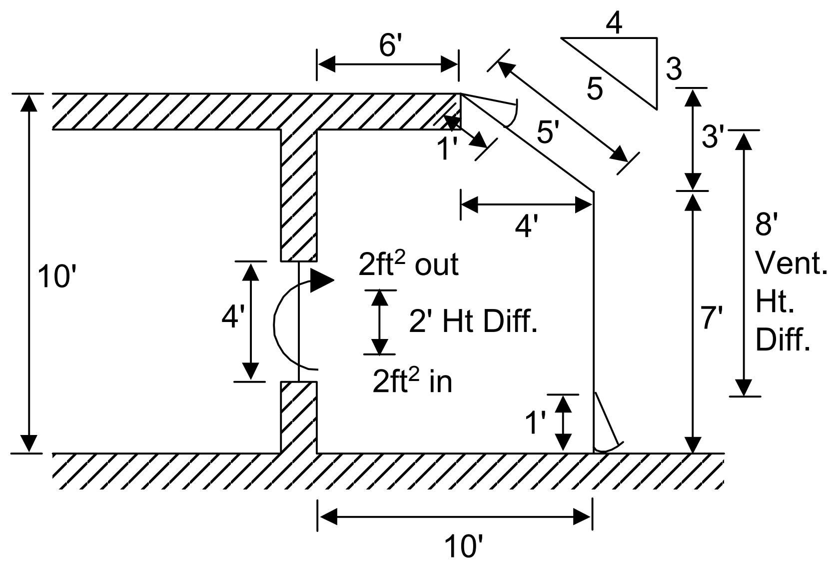


Figure 6-4 - Sunspace Section

Sunspaces are tested only for prototype A in five climate zones: 3, 9, 12, 14 and 16. A sunspace is added and the heating efficiency is modified accordingly. Each computer run must result in greater energy use than prototype A. The computer runs are summarized below. *Total of five runs.*

Table R6-5 – Sunspace Test Inputs

Run Label	Sunspace	Heating AFUE
03A53	Yes	0.55
09A53	Yes	0.29
12A53	Yes	0.54
14A53	Yes	0.54
16A53	Yes	0.64

The optional capability test also requires that the vendor demonstrate that the ACM correctly defines the standard design building and calculates the custom budget. This test involves running the standard design equivalent building for climate zone 12 and showing that the custom budget figures from computer run "12A53" are equal.

6.4 Side Fin Shading

Testing for side fins is performed relative to a modification of prototype A; the base building is rotated 30 degrees to the west. The test is performed in five climate zones: 3, 9, 12, 14 and 16. The specifications for the side fins are provided on the Commission's CALRES input file diskette as test file 12A54. Key features are covered below.

The side fins extend 40 feet from the surface of a window that is assumed to be 10 feet wide. The fins are 5 feet from the edge of the window. The top of the side fins are 20 feet above the top of the window. Side fins are separately added to the east and west sides of the building and the heating efficiency is modified accordingly. Each computer run must result in greater energy use than prototype A. *Total of five runs.*

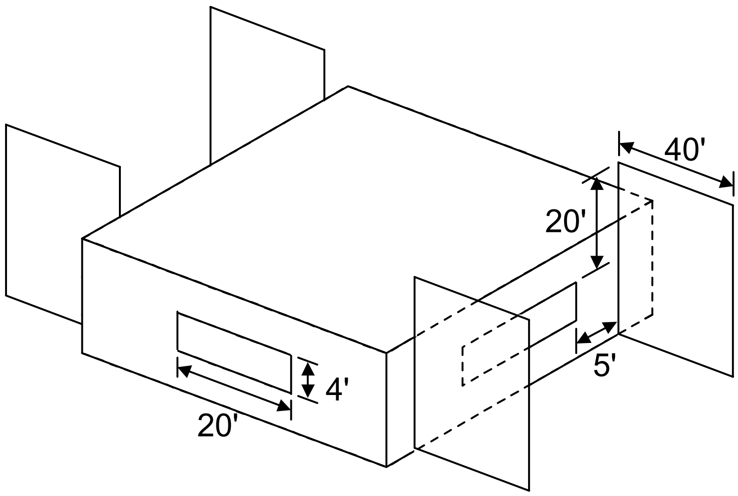


Figure 6-5 - Side Fins for Optional Capabilities Test

Table R6-6 - Side Fin Test Inputs

Run Label	Side Fins	Heating AFUE
03A54	Yes	0.65
09A54	Yes	0.40
12A54	Yes	0.62
14A54	Yes	0.65
16A54	Yes	0.70

The optional capability test also requires that the vendor demonstrate that the ACM correctly defines the standard design building and calculates the custom budget. This test involves running the standard design equivalent building for climate zone 12 and showing that the custom budget figures from computer run "12A54" are equal. The standard design equivalent building is included on the CALRES diskette as the input file labeled "12A54C".

6.5 Exterior Mass Walls

The test for exterior mass walls is made relative to prototype A in five climate zones: 3, 9, 12, 14 and 16. All of the exterior walls of the building are assumed to be of mass construction: The mass is assumed to be 12 inches thick with a volumetric heat capacity of 10 Btu/F-cf and a conductivity of 1.064. The outside surface of the mass wall is modeled with a U-value of 2.63 (R = 0.38) to approximate the effect of an air film. Insulation is assumed to be on the inside surface of the wall. This insulation is varied for each climate zone. Each computer run must result in greater energy use than prototype E. *Total of five runs.*

Table R6-7 – Exterior Mass Wall Inputs

Run Label	Exterior Mass Walls	Interior R-value
03A55	yes	4.20
09A55	yes	1.20
12A55	yes	3.575
14A55	yes	4.825
16A55	yes	6.95

The optional capability test also requires that the vendor demonstrate that the ACM correctly defines the standard design building and calculates the custom budget. This test involves running the standard design equivalent building for climate zone 12 and showing that the custom budget figures from computer run "12A55" are equal. The standard design equivalent building is included as the input file labeled "12A55C" on the CALRES input file diskette.

6.6 Optional Water Heating Capabilities Tests

6.6.1 Solar and Wood Stove Boiler Water Heating

Optional water heating capabilities include solar water heating and wood stove boiler-assisted water heating. Energy credit may be taken for the use of these technologies through the use of multipliers that adjust the water heating loads. For solar this adjustment is the Solar Savings Fraction (SSFj) derived from an f-Chart analysis and for wood stove boilers this adjustment is called the Wood Stove Adjustment Factor (WSAFj). These adjustments are used as shown in Section 4.21

6.6.2 Combined Hydronic Space/Water Heating

Combined hydronic space/water heating is a system whereby a water heater is used to provide both space heating and water heating. Hydronic systems or water heaters dedicated solely to space heating are covered in Section 6.6.3.

For combined hydronic systems, an effective AFUE, or for electric water heaters or heat pumps, an effective HSPF, is calculated and used in the space heating energy calculations. When a fan coil is used to distribute heat, the fan energy and the heat contribution of the fan motor must be considered. This shall automatically be added when the distribution type is "ducts". The effective AFUE or HSPF is calculated according to the following equations for each water heater type.

6.6.2.1 Storage Gas Water Heater

When storage gas water heaters are used in combined hydronic applications and there is no air distribution fan, then the effective AFUE is given by the following equation.

Equation 6-3

$$AFUE_{eff} = RE - \frac{PL}{RI}$$

Where

$AFUE_{eff}$ =	The effective AFUE of the gas water heater in satisfying the space heating load.
RE =	The recovery efficiency of the gas water heater. A default value of 0.76 may be assumed if the recovery efficiency is unknown.
PL =	Pipe losses (kBtu/h). This can be assumed to be zero when less than 10 feet of the piping between the water heater storage tank and the fan coil or other heating elements is located in unconditioned space.

Equation 6-4

$$PL = \sum_{i=1}^{n} \frac{FT_i \times PLR_i}{8760}$$

RI =	The rated input of the gas water heater (kBtu/h).

When there is an air distribution fan, then the energy used by the fan and the heat contributed by the fan is considered in the same manner as it is for a furnace (see Section 4.18)

6.6.2.2 Storage Electric Water Heater

The HSPF of storage water heaters used for space heating in a combined hydronic system is given by the following equations. If the system has a fan coil, the $HSPF_{eff}$ is used. $HSPF_{w/o\_fan}$ is used if there is no fan coil.

Equation 6-5

$$HSPF_{eff} = \frac{1 + .005(3.413)}{\left[\dfrac{1}{HSPF_{w/o\_fan}}\right] + .005}$$

Equation 6-6

$$HSPF_{w/o\_Fan} = 3.413\left[\frac{1 - \dfrac{PL}{3.413kWi}}{1 + \dfrac{W_{PUMP}}{1000kWiI}}\right]$$

Where:

$HSPF_{eff}$ = The effective HSPF of the electric water heater in satisfying the space heating load.

W_{pump} = The watts of the pump which circulates water between an electric storage water heater and the fan coil

PL = Pipe losses (kBtu/h). This can be assumed to be zero when less than 10 feet of the piping between the water heater storage tank and the fan coil or other heating elements is located in unconditioned space.

kWI = The kilowatts of input to the water heater.

6.6.2.3 Heat Pump Water Heater

The HSPF of heat pump water heaters used for space heating in a combined hydronic system is given by the following equations. If the system has a fan coil, the $HSPF_{eff}$ is used. $HSPF_{w/o\_fan}$ is used if there is no fan coil.

$$HSPF_{eff} = \frac{1+.005(3.413)}{\left[\frac{1}{HSPF_{w/o\_fan}}\right]+.005} \qquad \text{Equation 6-7}$$

$$HSPF_{w/o\_Fan} = 3.413\left(\frac{RE_{hp}}{CZ_{adj}} - \frac{PL}{3.413kWi}\right) \qquad \text{Equation 6-8}$$

Where:

$HSPF_{eff}$ = The effective HSPF of the heat pump water heater in satisfying the space heating load.

RE_{hp} = The recovery efficiency of the heat pump water heater. The following equation may be used as a default if the recovery efficiency is not known.

$$\mathrm{RE}_{\mathrm{hp}} = \frac{1}{\frac{1}{EF_{DOE}} - 0.1175} \qquad \text{Equation 6-9}$$

CZ_{adj} = The climate zone adjustment (see water heating calculation method) (see Table R 4-9).

PL = Pipe losses (kBtu/h). This can be assumed to be zero when less than 10 feet of the piping between the water heater storage tank and the fan coil or other heating elements is located in unconditioned space.

kWI = The kilowatts of input.

EF_{DOE} = The energy factor of the heat pump water heater when tested according to the DOE test procedure.

6.6.2.4 Pipe Losses

Pipe losses must be considered when pipes between the water heater storage tank and the fan coil or other heating element are located in unconditioned space. To simplify compliance, pipe losses can be ignored when no more than ten feet of pipe (in plan view) is located in unconditioned space[23]. Hourly loss rates are given by the following equation.

Equation missing from Master files. Equation 6-10

PL = Hourly pipe loss (kBtu/h).

PLR_i = The annual pipe loss rate per foot of length for the i^{th} pipe (kBtu/y-ft).

FT_i = The length in feet of the i^{th} pipe located within unconditioned space. Can be assumed to be zero if less than ten feet in plan view.

n = The number of unique pipe size or insulation conditions.

The annual pipe loss rate per foot of length (PLRi) is calculated from the following equation

$$PLR_i = 8.76\left(\frac{T_s - T_a}{\frac{\ln\left(\frac{D_{io}}{D_{po}}\right)}{2\,\pi\,Ki} + \frac{1}{\pi\,ha\,D_{io}}}\right) \qquad \text{Equation 6-11}$$

Where

8.76 = Conversion factor from Btu/hour to kBtu/year

T_s = Supply Temperature. This is assumed to be a constant 135 F.

T_a = Ambient Temperature. This is assumed to be 60.3 in all California climate zones.

D_{io} = Outside diameter of insulation. ft (actual not nominal).

D_{po} = Outside diameter of pipe, ft (actual not nominal).

Ki = Insulation conductivity, constant 0.023 Btu/h-ft-F

ha = Air film coefficient, constant 1.65 Btu/h-ft^2-F

[23] PL would have a value of about 0.10 for 10 feet of one inch pipe with R-4 insulation, which is required (see page 25 of ACM Approval Manual).

Pipe loss rates (PLR) values for typical conditions are shown in the table below

Table R6-8- Annual Pipe Loss Rates (kBtu/y-ft)

		Insulation Thickness		
Nominal Pipe Size	**None**	**1/2 inch**	**3/4 inch**	**1 inch**
1/2 inch		71.6	60.9	54.2
3/4 inch		91.1	75.8	66.6
1 inch		109.9	90.1	78.1
1 - 1/2 inch		146.7	117.5	100.3
2 inch		182.9	144.3	121.7

6.6.2.5 Tests

Prototype A is used for this test, but combined hydronic systems are substituted for the gas furnace in the basecase. Three types of combined hydronic systems are tested -- labeled K, L and M.

K A 75 gallon storage gas water heater is used for both space conditioning and water heating. Hot water base boards are used for heat distribution and insulated pipes are located in unconditioned space.

L An electric water heater is used for both space conditioning and water heating and air is distributed through a fan coil system that delivers air to ducts located in an attic.

M An electric heat pump is used for both space conditioning and water heating. Distribution is provided through hot water baseboards. All pipes are located within conditioned space.

The specifications for these three systems are shown in Table R6-9 below. The AFUEeff and HSPF w/o fan must match the values shown in the table.

Table R6-9 -Combined Hydronic Test Results

		K	**L**	**M**
Water Heater Type		SG	SE	HP
Recovery Efficiency	unitless	0.7800	n.a.	n.a.
Rated Input	kBtu/sf	60.0000	n.a.	n.a.
Rated Input	kW	n.a.	5.0000	n.a.
Wpump	W	n.a.	60.0000	n.a.
EF	unitless	n.a.	n.a.	2.0000
Pipe Length	ft	100.0000	n.a.	n.a.
Run Label		AFUEeff	HSPF w/o fan	HSPF w/o fan
03A56		0.768	3.37	9.01
09A56		0.768	3.37	9.70
12A56		0.768	3.37	8.34
14A56		0.768	3.37	8.58
16A56		0.768	3.37	5.95

The optional capability test also requires that the vendor demonstrate that the ACM correctly defines the standard design building and calculates the custom budget. This test involves running the standard design equivalent building for climate zone 12 and showing that the custom budget figures from computer run "12A56" are equal. The standard design equivalent building is included in Appendix D and labeled "12A56C".

6.6.3 Dedicated Hydronic Systems

Dedicated hydronic systems have boilers or other heating devices which produce hot water that is distributed through the building for heating. Such systems are permitted when the AFUE is known and can be entered. If the systems have pipes located in unconditioned space, then the AFUE must be adjusted for the pipe losses.

When water heaters are used in hydronic systems for space heating alone (a separate water heater for domestic service), the water heater functions as a boiler and is required by NAECA to have a minimum AFUE of 0.80. The AFUE of a water heater if tested as a boiler would be approximately equal to the average of the EF and the RE, and will generally not meet the minimum NAECA requirement. Water heaters proposed for use in hydronic systems for space heating only must be tested as a boiler using the DOE AFUE and appropriate safety standard test procedures.

6.7 Building Additions

The low-rise residential Building Energy Efficiency Standards permit two ways of analyzing building additions using the performance approach. The addition may be analyzed alone, in which case the internal loads are prorated on a floor area basis. Alternatively, the addition may be analyzed together with the existing house. This second method permits improvements to be made to the existing house which may allow the building addition to have more glass or less insulation.

6.7.1 Addition Alone

When the addition is analyzed alone, the internal loads are prorated on a floor area basis in both the standard design and the proposed design runs. The total internal gain is based on the fractional dwelling unit value, which is used as the "Number-Dwelling-Units" in Equation 4.3 (see Section 4.5). An addition alone may not be modeled as zonal control.

$$IntGainAdd = IntGainTotal \times FractionalDwellingUnit \qquad \text{Equation 6-12}$$

$$FractionalDwellingUnit = CFAadd \div (CFAadd + CFAexisting) \qquad \text{Equation 6-13}$$

6.7.2 Addition Plus Existing

When the building addition is analyzed together with the existing building, the procedure described in Chapter 6 of the *Residential Manual*, is followed.

It is necessary to manage information about the existing building and the addition in four categories as described below. These may be grouped in each table or separate C-2R forms may be generated for each category of information.

1 Features of the existing building that will not be upgraded or changed.

2 The current condition of existing building features that will be modified or upgraded.

3 The improved condition of existing building features that are upgraded. The total surface areas in this category will usually be less than those in the second category because an existing wall is usually eliminated where the addition is attached to the existing building.

4 Features of the proposed building addition.

6.8 Solar Water Heating and Space Heating

Modeling of solar water heating and space heating systems is not an optional capability for residential ACMs, but ACMs must provide an input for the energy provided by solar or other nondepletable sources. These inputs are described in Chapter 4.

The Commission has approved the use of various versions of the f-Chart program for analyzing active solar systems. These programs may be used to estimate the energy credit to enter in the ACM. Guidelines for the use of f-Chart are included in Chapter 7 of the *Residential Manual*.

This Manual does not address approval of solar analysis programs. The application package for approval of solar water heating and space conditioning programs is included as Appendix G.

When a credit is taken for nondepletable energy, the ACM standard input reports must flag this and include a statement in the *Special Features and Modeling Assumptions* section of the reports. The ACM user must also attach supporting calculations or worksheets of Commission approved methods.

6.9 Form 3 Report Generator

This test requires that ACMs correctly calculate the U-value of several construction assemblies. These construction assemblies are shown in Appendix E. The Form 3 generator must produce the values indicated in Table R6-10 for U-value. Construction assembly U-values must be calculated in a manner consistent with the manner and examples shown in the *Residential Manual*, in the glossary under "R-value" and "U-value", and in Appendix E.

Table R6-10 - Form 3 Generator Results

Construction Assembly Code	U-value
W.19.2x6.16	.065
R.38.2x4.24	.025
R.22.2x4.24	.041
RP.22.2x6.48	.044
FC.30.2x10.16	.028
FX.30.2x10.16	.034

6.10 Exceptional Methods Which May Be Approved In The Future

The Commission may approve additional Exceptional Methods in the future, for instance, additional water heating credits. All approved ACMs must provide an input for space heating, space cooling and water heating systems to allow the user to enter a value for these possible credits. The ACM standard reports identify all non-zero values and place a statement in the *Special Features and Modeling Assumptions* section of the standard reports. The ACM user must include supporting calculations, worksheets or equipment specifications with the building permit application.

7. Home Energy Rating Systems (HERS) Required Verification And Diagnostic Testing

7.1. California Home Energy Rating Systems

The Commission is required to regulate home energy rating system (HERS) providers in California. These regulations appear in the California Code of Regulations, Title 20, Chapter 4, Article 8, Sections 1670-1675. Approved HERS providers are authorized to certify raters and maintain quality control over ratings. Ratings are based on visual inspection and diagnostic testing of the physical characteristics and energy efficiency features of dwelling units, as constructed. When the term "dwelling unit" is used in reference to Home Energy Rating Systems (HERS) Required Verification and Diagnostic Testing applied to multifamily buildings, it shall mean each dwelling unit within each multifamily building project. When the term "building owner" is used in this Chapter, it shall mean owner of the dwelling unit.

When compliance documentation indicates field verification and diagnostic testing of specific energy efficiency measures as a condition for complying with Title 24, an approved HERS provider and certified HERS rater shall be used to conduct the field verification and diagnostic testing. HERS providers and raters shall be considered special inspectors by building departments, and shall demonstrate competence, to the satisfaction of the building official, for the visual inspections and diagnostic testing. The HERS provider and rater shall be independent entities from the builder or subcontractor installer of the energy efficiency improvements being tested and verified, and shall have no financial interest in the installation of the improvements.

7.2. HERS Required Verification and Diagnostic Testing

HERS diagnostic testing and field verification is required for:

- duct air sealing,
- ACCA Manual D design and installation,
- Refrigerant charge and airflow measurement, and
- Building envelope sealing beyond improvements covered by default assumptions,

HERS field verification is required for:

- thermostatic expansion valves,
- duct surface area reductions, and
- duct location improvements beyond those covered by default assumptions.

These features shall be listed as *HERS Verification Required* features on the *Certificate of Compliance* (CF-1R) and the *Computer Method Summary* (C-2R). Such verification constitutes "eligibility and installation criteria" for these features. Field verified and diagnostically tested features must be described in the *Compliance Supplement*.

7.3. Installation Certification

When compliance includes duct sealing, ACCA Manual D design and installation, refrigerant charge and airflow measurement or envelope sealing, builder employees or subcontractors shall:

- complete diagnostic testing, and

- certify on the CF-6R the diagnostic test results and that the work meets the requirements for compliance credit.

For refrigerant charge and airflow measurement when the outside temperature is below 55°F, the installer shall follow the alternate charge and airflow measurement procedure described in Appendix K, Section 3. Builder employees or subcontractors using these procedures shall certify on the CF-6R that they used these procedures, the diagnostic results, that the work meets the requirements for compliance credit, and that they will return to correct refrigerant charge and airflow if the HERS rater determines at a later time when the outside temperature is above 55°F that correction is necessary.

For duct sealing completed at the rough-in stage of construction using aerosol sealant closures, builder employees or subcontractors shall:

- at rough-in, complete the fan pressurization test and certify on the CF-6R the diagnostic results,
- after installation of the interior finishing wall, verify sealing of the ducts using either the house pressure test or the pressure pan test or by visual inspection of all duct connections (including duct to air handler connections), and
- certify on the CF-6R the diagnostic results and that the work meets the requirements for compliance credit.

When compliance includes a thermostatic expansion valve, duct surface area reductions and duct location improvements beyond those covered by default assumptions, builder employees or subcontractors shall:

- record the feature on the CF-6R,
- record on the CF-6R the duct surface area in each duct location, and
- certify on the CF-6R that the duct surface area and locations match those on the plans, and that the work meets the requirements for compliance credit.

Installation certifications are required for each and every dwelling unit.

7.4. HERS Verification Procedures

At the builder's option HERS field verification and diagnostic testing shall be completed either for each dwelling unit or for a sample of dwelling units. Dwelling units in the sample shall be in the same subdivision or multifamily housing development. Field verification and diagnostic testing for compliance credit for duct sealing shall use the diagnostic duct leakage from fan pressurization of ducts in Section 4.3.8.2.1 of Appendix F.

Field verification and diagnostic testing for compliance credit for refrigerant charge and airflow measurement shall use the standard charge and airflow measurement procedure specified in Appendix K. Field verification and diagnostic testing shall not use the alternate charge and airflow measurement procedure. Field verification and diagnostic testing shall be scheduled and completed when the outside temperature is above 55°F.

The builder shall provide the HERS provider a copy of the CF-6R containing the installation certifications required in Section 7.3. Prior to completing field verification and diagnostic testing, the HERS rater shall first verify that the installation certifications have been completed.

If the builder chooses the sampling option, the procedures described in this section shall be followed. Sampling procedures described in this section shall be included in the *Compliance Supplement*.

7.5. Initial Field Verification and Testing

The HERS rater shall diagnostically test and field verify the first dwelling unit of each model. To be considered the same model, dwelling units shall be in the same subdivision or multifamily housing development and have the same energy designs and features, including the same floor area and volume, for each dwelling unit, as shown on the CF-1R. This initial testing allows the builder to identify and correct any potential construction flaws or practices in the build out of each model. If field verification and diagnostic testing determine that the requirements for compliance are met, the HERS rater shall provide a signed and dated *Certificate of Field Verification and Diagnostic Testing* (CF-4R) to the builder and the HERS provider

7.5.1. Sample Field Verification and Testing

After the initial testing is completed, the builder shall identify a group of dwelling units from which a sample will be selected for testing, and notify the HERS provider. The group shall include only dwelling units expected to be ready for diagnostic testing within a maximum 180-day period.

The builder shall identify the group of dwelling units by location of County, City and either the street address or the subdivision and lot number, or the multifamily housing project name and shall identify the names and license numbers of subcontractors responsible for the duct installation, duct sealing, thermostatic expansion valve installation, refrigerant charge and airflow measurement or envelope sealing that requires diagnostic testing or field verification. The builder may add additional dwelling units to the group by notifying the HERS provider as long as they are completed within the maximum 180-day period.

The HERS rater shall select a minimum of one out of every seven sequentially completed dwelling units from the group, rounded up to the next whole number, for diagnostic testing and field verification as described in Section 7.4. When several dwelling units are ready for testing at the same time, the HERS rater shall randomly select the dwelling units to be tested. The HERS rater shall diagnostically test and field verify the dwelling units selected by the HERS rater.

If field verification and diagnostic testing determines that the requirements for compliance are met, the HERS rater shall provide a signed and dated *Certificate of Field Verification and Diagnostic Testing* to the builder and the HERS provider. The *Certificate of Field Verification and Diagnostic Testing* shall report the successful diagnostic testing results and conclusions regarding compliance for the tested dwelling unit.

The HERS rater shall also provide a signed and dated *Certificate of Field Verification and Diagnostic Testing* to the builder and the HERS provider for up to six additional dwelling units from the group. The *Certificate* shall not be provided for dwelling units in which the feature requiring field verification and diagnostic testing has not been installed, sealed or completed.

The maximum 180-day period shall begin on the date of the first *Certificate of Field Verification and Diagnostic Testing* for the group and shall end either with the date of the last verified test from the group or 180 days, whichever is less. Once all homes in the group have been certified, the 180 day clock is reset. Dwelling units within the group for which a *Certificate of Field Verification and Diagnostic Testing* has not been completed within 180 days from the date of the first *Certificate of Field Verification and Diagnostic Testing* for the group, as determined by the HERS provider, shall either be individually tested or be included in a group of dwelling units in a subsequent sample period.

Whenever the builder changes subcontractors who are responsible for the feature that is being diagnostically field verified and tested, the builder shall notify the HERS rater of any subcontractors who have changed, and terminate sampling for the identified group. All dwelling units using *HERS Required Verification* features for compliance that were installed by previous subcontractors or were subject to verification and testing under the supervision of a previous HERS provider, for which the builder does not have a completed *Certificate of Field Verification and Diagnostic Testing*, shall either be individually tested or included in a separate group for sampling. Dwelling units with installations completed by new subcontractors shall either be individually tested or shall be included in a new sampling group following a new *Initial Field Verification and Testing*.

The HERS rater shall not notify the builder when sample testing will occur prior to the completion of the work that is to be tested. After the HERS rater notifies the builder when testing will occur, the builder shall not do additional work on the features being tested.

7.5.2. Re-sampling, Full Testing and Corrective Action,

When a failure is encountered during sample testing, the HERS rater shall conduct re-sampling to assess whether that failure is unique or the rest of the dwelling units are likely to have similar failings. The HERS provider shall select for re-sampling one out of every seven of all of the untested dwelling units in the group, rounded up to the next whole number.

If testing in all dwelling units in the re-sample confirms that the requirements for compliance credit are met, then the dwelling unit with the failure shall not be considered an indication of failure in the other dwelling units in the group. The builder shall take corrective action for the dwelling unit with the failure, and then the HERS rater shall retest to verify compliance and issue a signed and dated *Certificate of Field Verification and Diagnostic Testing* to the builder. Sampling shall then resume for the remainder of the group.

If field verification and testing in any of the dwelling units in the re-sample results in a second failure, the builder shall take corrective action in all unoccupied dwelling units in the group that have not been tested but for which a *Certificate of Field Verification and Diagnostic Testing* has been completed. The HERS rater shall conduct field verification and diagnostic testing in each of these dwelling units to verify that problems have been corrected and that the requirements for compliance have been met, and shall report to the HERS provider.

Builders shall offer at no charge to building owners in occupied dwelling units in the group to complete field verification and testing and corrective action if necessary. Building owners may decline this offer. Builders shall report the identifying location of any dwelling unit in which the building owner declines field verification and testing and corrective action to the HERS provider. The HERS provider shall verify that the builder has made this offer. If a building owner in an occupied dwelling unit declines this offer, field verification, testing and corrective action will not be required for that dwelling unit and the dwelling unit will no longer be considered a part of the group. If a building owner accepts this offer, the builder shall take corrective action. The HERS rater shall then conduct field verification and diagnostic testing to verify that problems have been corrected and that the requirements for compliance have been met, and shall report to the HERS provider.

The HERS provider shall file a report with the building department explaining all action taken (including field verification, testing, corrective action, offers to building owners for testing and corrective action and building owner declines of such offers) to bring into compliance dwelling units for which a signed and dated *Certificate of Field Verification and Diagnostic Testing* has been provided to the builder. If corrective action requires work not specifically exempted by Section 112 of the UMC or Section 106 of the UBC, the builder shall obtain a permit from the building department prior to commencement of any of the work.

Until corrections, field verification and testing of all dwelling units in the group have been completed or building owners in occupied dwelling units have declined corrective action, sampling of additional dwelling units in the group shall cease. If additional dwelling units in the group are completed during the time required to correct, field verify and test the previously completed dwelling units in the group, the rater shall individually field verify and diagnostically test those additional dwelling units to confirm that the requirements for compliance credit are met. Once corrections, field verification and testing is completed for all dwelling units that have a *Certificate of Field Verification and Diagnostic Testing*, excepting those where building owners have declined corrective action, the builder shall either resume sampling for the remainder of the dwelling units in the group or terminate the group.

Corrections shall not be made to a sampled dwelling unit to avoid a failure. If corrections are made to a sampled dwelling unit, corrections, field verification and testing shall be performed on 100% of the dwelling units in the group.

7.6. Responsibilities and Documentation

7.6.1. Builder

Builder employees or subcontractors responsible for completing either diagnostic testing, visual inspection or verification as specified in Section 7.3 shall certify the diagnostic testing results and that the work meets the requirements for compliance credit on the CF-6R.

The builder shall provide the HERS provider with the identifying location of the group of dwelling units to be included in the sample for field verification and diagnostic testing and the expected date that sampling may begin. The builder shall provide the HERS provider a copy of the CF-6R signed by the builder employees or sub-contractors certifying that diagnostic testing and installation meet the requirements for compliance credit.

The builder shall provide a *Certificate of Field Verification and Diagnostic Testing* signed and dated by the HERS rater to the building official in conjunction with requests for final inspection for each dwelling unit.

When resampling reveals a failure, builders shall offer at no charge to building owners in occupied dwelling units in the group to complete field verification, testing and corrective action if necessary. Building owners may decline to have field verification and testing and corrective action completed. Builders shall report the identifying location of any dwelling unit in which the building owner declines field verification and testing and corrective action to the HERS provider. Builders shall take corrective action as required in all unoccupied dwelling units in the group and in occupied dwelling units in the group where building owners have accepted field verification, testing and corrective action.

7.6.2. HERS Provider and Rater

The HERS provider shall maintain a list of the dwelling units in the group from which sampling is drawn, the dwelling units selected for sampling, the dwelling units sampled and the results of the sampling, the dwelling units selected for re-sampling, the dwelling units that have been tested and verified as a result of re-sampling, the corrective action taken, and copies of all *Certificates of Field Verification and Diagnostic Testing* for a period of five years.

The HERS rater providing the diagnostic testing and verification shall sign and date a *Certificate of Field Verification and Diagnostic Testing* certifying that he/she has verified that the requirements for compliance credit have been met. *Certificates of Field Verification and Diagnostic Testing* shall be provided for the tested dwelling unit and each of up to six other dwelling units from the group for which compliance is verified based on the results of the sample. The HERS rater shall provide this certificate to the builder and the HERS provider.

The HERS Rater shall provide a separate *Certificate of Field Verification and Diagnostic Testing* for each dwelling unit the rater determines has met the diagnostic requirements for compliance. The HERS rater shall identify on the *Certificate of Field Verification and Diagnostic Testing* if the dwelling unit has been tested or if it was an untested dwelling unit approved as part of sample testing. The HERS rater shall not sign a *Certificate of Field Verification and Diagnostic Testing* for a dwelling unit that does not have a CF-6R signed by the installer as required in Sections 7.2 and 7.5.1.

If field verification and testing on a sampled dwelling unit identifies a failure to meet the requirements for compliance credit, the HERS rater shall report to the HERS provider and the builder that re-sampling will be required.

If re-sampling identifies another failure, the HERS rater shall report to the HERS provider and the builder that corrective action and diagnostic testing and field verification will be required for all the untested dwelling units in the group. This report shall specify the identifying location of all dwelling units that must be corrected and fully tested.

The HERS provider shall also report to the builder once diagnostic testing and field verification has shown that the failures have been corrected in all of the dwelling units except those for which the building owner has declined field verification, testing and corrective action.

When individual dwelling unit testing and verification confirms that the requirements for compliance have been met, the HERS rater shall provide a *Certificate of Field Verification and Diagnostic Testing* for each previously untested/unverified dwelling unit in the group and for each additional dwelling unit of the same model completed during the time required to correct, verify and test the previously untested/unverified dwelling units in the group.

The HERS provider shall file a report with the building department explaining all action taken (including field verification, testing, corrective actions, offers to building owners for testing and corrective action, and building owner declines of such offers) to bring into compliance dwelling units for which a signed and dated *Certificate of Field Verification and Diagnostic Testing* has been provided to the builder.

7.6.3. Building Department

The building department at its discretion may require independent testing and field verification in conjunction with the building department's required inspections, and/or observe the diagnostic testing and field verification performed by builder employees or subcontractors and the certified HERS rater in conjunction with the building department's required inspections to corroborate the results documented in installer certifications, and in the *Certificate of Field Verification and Diagnostic Testing*.

For dwelling units that have used a compliance alternative that requires field verification and diagnostic testing, the building department shall not approve a dwelling unit for occupancy until the building department has received from the builder a *Certificate of Field Verification and Diagnostic Testing* that has been signed and dated by the HERS rater.

If necessary to avoid delay of approval of dwelling units completed when outside temperatures are below 55°F, building departments may approve compliance credit for refrigerant charge and airflow measurement when installers have used the alternate charging and airflow measurement procedure described in Appendix K, Section 3. This approval will be on the condition that installers provide a signed agreement (CF-6R) to the builder with a copy to the building department to return to correct refrigerant charge and airflow if the HERS rater determines at a later time when the outside temperature is above 55°F that correction is necessary.

8 Compliance Supplement

Each ACM vendor is required to publish a Compliance Supplement to the normal program users manual. The Compliance Supplement serves two major purposes. First, it helps building permit applicants to use the ACM correctly and to prepare complete documentation of their analyses. Second, it helps building officials to check permit applications for compliance with the low-rise residential Building Energy Efficiency Standards. As a result, it helps to assure that both the performance standards and the ACM are used properly.

The Compliance Supplement must describe the specific procedures for using the ACM for compliance with the Building Energy Efficiency Standards. The supplement must provide instructions for preparing the building input, using the correct fixed and restricted inputs, and for using each of the optional capabilities for which the ACM is approved. Also included are procedures for generating the standard reports and documenting the analysis. A sample of a properly documented building analysis must be included.

All Compliance Supplements must be written in a clear and concise manner and with a common organization and format. Variations in format may be approved by the CEC, however, to allow for the differences between ACMs. This will assure consistency between the compliance supplements of different ACMs, simplifying the enforcement task of building officials. Also, vendors of approved ACMs are required to make copies of their compliance supplement available to all building departments in California.

The following sections describe the information that must be included in all compliance supplements. It also presents the required organization for that information.

8.1 CEC Approval

This section includes a copy of the official CEC notice of approval of the ACM. The notice may include restrictions or limitations on the use of the ACM. It will also include the date of approval, and may include an expiration date for approval as well. The notice will indicate which optional capabilities the ACM is approved for and other restrictions on its use for compliance. The CEC will provide this notice upon completion of evaluation of the ACM application.

8.2 Program Capabilities

This section discusses the program capabilities, with supporting written material explaining, as necessary, how the ACM treats each one. Reference may be made to non-compliance sections of the ACM Users Manual for more complete descriptions, if they exist.

8.3 Standard Input/Output Report

This section explains how to use the program to prepare the standard input/output reports.

8.4 Fixed and Restricted Inputs

Approved ACMs must automatically use the standard fixed and restricted inputs for the standard design run. It must also default to the standard assumptions for the proposed design run. When the alternative fixed and restricted inputs are used for the proposed design run, the ACM must report this in the *Special Features and Modeling Assumptions* sections of the standard reports.

This section of the Compliance Supplement explains the fixed and restricted inputs and how they are invoked in the ACM. This is especially important if the ACM offers the possibility of non-compliance runs which can deviate from the fixed and restricted inputs.

8.5 Preparing Basic Input

This section covers the basic use of the ACM for compliance. Optional capabilities are described in greater detail. Reference may be made to the users manual, but this section should include a complete summary of all inputs and/or commands necessary for compliance.

8.6 Optional Capabilities

This section explains the procedures for using each of the optional capabilities of the ACM. It is a parallel section to the basic inputs section above. The section for each optional capability should explain how to prepare inputs, how to document assumptions, and what the limitations are of each analysis capability.

8.7 Special Features and Modeling Assumptions

This section explains the use of the Special Features and Modeling Assumptions listing to highlight the importance of verifying the special features and the aspects of those features that were modeled to achieve compliance.

8.8 HERS Required Verification

This section explains the use of the HERS Required Verification listing to highlight the special features that require diagnostic testing by a certified home energy rater under the supervision of a CEC approved HERS provider to assure proper installation and verification. This section may rely on the information provided in Chapter 7, other sections of this manual, or may refer to other Commission documents.

8.9 Checklist for Compliance Submittal

This section should contain a concise checklist of all items that must be included in a compliance submittal to a building official using the ACM.

8.10 Sample Compliance Documentation

This section should include a complete set of compliance documentation for a sample building. The building need not be overly complex, nor need it include every program capability. The example should, however, include all documentation and standard reports that would normally be submitted. This example will serve as a model to ACM users and building officials of what a proper compliance submittal should look like.

8.11 Compliance Statement

The following statement must appear within the first several pages of the Supplement:

> [ACM Name] may be used to show compliance with California's Residential Building Energy Efficiency Standards.

8.12 Related Publications

The Compliance Supplement should refer users to the following related CEC publications and where to obtain them:

- *2001 Building Energy Efficiency Standards* (P400-00-001)
- *2001 Residential Manual* (P400-00-029)

Both publications are available from:

California Energy Commission
Publications Unit
1516 Ninth Street
Sacramento CA 95814
(916) 654-5200

9 Vendor Requirements

9.1 Availability to CEC

All ACM vendors are required to submit at least one version of the ACM to the California Energy Commission. An updated copy or access to the approved version of the ACM must be kept by the CEC to maintain approval for compliance usage of the ACM. The CEC agrees not to duplicate the ACM except for the purpose of analyzing it, for verifying building compliance with the ACM, or to verify that only approved versions of the ACM are used for compliance.

9.2 Building Department Support

ACM vendors must provide a copy of the ACM Compliance Supplement to all local building enforcement agencies who request one in writing.

9.3 User Support

It is expected that ACM vendors will offer support to their users with regard to the use of the ACM for compliance purposes. Vendors may charge a fee for user support.

9.4 ACM Vendor Demonstration

The CEC may request ACM vendors to physically demonstrate their program's capabilities. One or more demonstrations may be requested before approval is granted.

Appendix RF – Standard Procedure for Determining the Seasonal Energy Efficiencies of Residential Air Distribution Systems

RF1.0 ~~Introduction~~Purpose and Scope

ACM RF contains procedures for measuring the air leakage in forced air distribution systems and for calculating the annual and hourly duct efficiency for energy calculations. ACM RF applies to air distribution systems in low-rise residential buildings. It also applies to nonresidential buildings, but only for single zone HVAC systems serving 5,000 ft² or less and with the ductwork located in the space between an insulated ceiling and the roof.

~~This appendix describes the measurement and calculation methods for determining air distribution system efficiency.~~

RF2.0 Definitions

***aerosol sealant closure system**:* A method of sealing leaks by blowing aerosolized sealant particles into the duct system and which must include minute-by-minute documentation of the sealing process.

floor area :The floor area of enclosed conditioned space on all floors of a building, as measured at the floor level of the exterior surfaces enclosing the conditioned space.

delivery effectiveness :The ratio of the thermal energy delivered to the conditioned space and the thermal energy entering the distribution system at the equipment heat exchanger.

distribution system efficiency :The ratio of the thermal energy consumed by the equipment with the distribution system to the energy consumed if the distribution system had no losses or impact on the equipment or building loads.

equipment efficiency :The ratio between the thermal energy entering the distribution system at the equipment heat exchanger and the energy being consumed by the equipment.

~~***equipment factor*** : F_{equip} is the ratio of the equipment efficiency including the effects of the distribution system to the equipment efficiency of the equipment in isolation.~~

***fan flowmeter device**:* A device used to measure air flow rates under a range of test pressure differences.

flow capture hood: A device used to capture and measure the airflow at a register.

load factor : F_{load} is the ratio of the building energy load without including distribution effects to the load including distribution system effects.

pressure pan : a device used to seal individual forced air system registers and to measure the static pressure from the register.

radiant barrier : a surface of low emissivity (less than 0.05) placed inside an attic or roof space to reduce radiant heat transfer.

recovery factor : F_{recov} is the fraction of energy lost from the distribution system that enters the conditioned space.

thermal regain: The fraction of delivery system losses that are returned to the building.

RF3.0 Nomenclature

a_r = duct leakage factor (1-return eakage) for return ducts

a_s = duct leakage factor (1-supply leakage)p for supply ducts

A_{floor} = conditioned floor area of building, ft^2

$A_{r,out}$ = surface area of return duct outside conditioned space, ft^2

$A_{r,attic}$ = return duct area in attic, ft^2

$A_{r,base}$ = return duct area in basement, ft^2

$A_{r,crawl}$ = return duct area in crawlspace, ft^2

$A_{r,gar}$= return duct area inside garage, ft^2

$A_{s,out}$ = surface area of supply duct outside conditioned space, ft^2

$A_{s,attic}$ = supply duct area in attic, ft^2

$A_{s,base}$ = supply duct area in basement, ft^2

$A_{s,crawl}$ = supply duct area in crawlspace, ft^2

$A_{s,gar}$ = supply duct area inside garage, ft^2

$A_{s,in}$ = supply duct area inside conditioned space, ft^2

B_r = conduction fraction for return

B_s = conduction fraction for supply

DE = delivery effectiveness

DE_{design} = design delivery effectiveness

$DE_{seasonal}$ = seasonal delivery effectiveness

E_{equip} = rate of energy exchanged between equipment and delivery system, Btu/hour

~~$F_{cycloss}$ = cyclic loss factor~~

~~F_{equip} = load factor for equipment~~

~~F_{flow} = load factor for fan flow effect on equipment efficiency~~

~~F_{leak} = fraction of system fan flow that leaks out of supply or return ducts~~

F_{load} = load factor for delivery system

F_{recov} = thermal loss recovery factor

F_{regain} = thermal regain factor

K_r = return duct surface area coefficient

K_s = supply duct surface area coefficient

N_{story} = number of stories of the building

P_{sp} = pressure difference between supply plenum and conditioned space [Pa]

P_{test} = test pressure for duct leakage [Pa]

Q_e = Flow through air handler fan at operating conditions, cfm

$Q_{total,25}$ = total duct leakage at 25 Pascal, cfm

R_r = thermal resistance of return duct, h ft^2 F/Btu

R_s = thermal resistance of supply duct, h ft^2 F/Btu

$T_{amb,r}$ = ambient temperature for return, F

$T_{amb,s}$ = ambient temperature for supply, F

T_{attic} = attic air temperature, F

T_{base} - return duct temperature in basement, F

T_{crawl} - return duct temperature in crawlspace, F

T_{design} = outdoor air design temperature, F

T_{ground} = ground temperature, F

T_{gar} = temperature of garage air, F

T_{in} = temperature of indoor air, F

T_{rp} = return plenum air temperature, F

$T_{seasonal}$ = outdoor air seasonal temperature, F

T_{sp} = supply plenum air temperature, F

ΔT_e = temperature rise across heat exchanger, F

ΔT_r = temperature difference between indoors and the ambient for the return, F

ΔT_s = temperature difference between indoors and the ambient for the supply, F

$\eta_{dist,seasonal}$ = seasonal distribution system efficiency

RF4.0 Air Distribution Diagnostic Measurement and Default Assumptions

RF4.1 Instrumentation Specifications

The instrumentation for the air distribution diagnostic measurements shall conform to the following specifications:

RF4.1.1 Pressure Measurements

All pressure measurements shall be measured with measurement systems (i.e. sensor plus data acquisition system) having an accuracy of ± 0.2 Pa. All pressure measurements within the duct system shall be made with static pressure probes.

RF~~4.1.2 Fan Flow Measurements~~

~~All measurements of distribution fan flows shall be made with measurement systems (i.e. sensor plus data acquisition system) having an accuracy of ±5% reading or ±5 cfm whichever is greater.~~

RF4.1.2~~3~~ Duct Leakage Measurements

The measurement of air flows during duct leakage -testing shall have an accuracy of ±3% of measured flow using digital gauges.

All instrumentation used for ~~fan flow and~~ duct leakage diagnostic measurements shall be calibrated according to the manufacturer's calibration procedure to conform to the above accuracy requirement. All testers performing diagnostic tests shall obtain evidence from the manufacturer that the equipment meets the accuracy specifications. The evidence shall include equipment model, serial number, the name and signature of the person of the test laboratory verifying the accuracy, and the instrument accuracy. All diagnostic testing equipment is subject to re-calibration when the period of the manufacturer's guaranteed accuracy expires.

RF4.2 Apparatus

~~4.2.1 System Fan Flows~~

~~HVAC system fan flow shall be measured using one of the following methods.~~

~~*4.2.1.1 Plenum pressure matching measurement*~~

~~The apparatus for measuring the system fan flow shall consist of a duct pressurization and flow measurement device (subsequently referred to as a fan flowmeter [see section 4.3.7.2.2.]) meeting the specifications in 4.1.3, a static pressure transducer meeting the specifications in Section 4.1.1, and an air barrier between the return duct system and the air handler inlet. The measuring device shall be attached at the air handler blower compartment door. All registers shall be in their normal operating condition. The static pressure probe shall be fixed to the supply plenum so that it is not moved during this test.~~

~~*4.2.1.2 Flow hood measurement*~~

~~A flow hood meeting the specifications in section 4.1.2. can be used to verify the fan flow at the return register(s) after the completion of a rough-in duct leakage measurement. All registers shall be in their normal operating position. Measurement(s) shall be taken at the return grill(s).~~

~~*4.2.2 Duct Leakage*~~

The apparatus for fan pressurization duct leakage measurements shall consist of a duct pressurization and flow measurement device meeting the specifications in Section 4.1~~.3~~.

RF4.3 Procedure

The following sections identify input values for building and HVAC system (including ducts) using either default or diagnostic information.

RF4.3.1 Building Information and Defaults

The calculation procedure for determining air distribution efficiencies requires the following building information:

1. Climate zone for the building,
2. Conditioned floor area,
3. Number of stories,
4. Supply duct location and
5. Floor type.

~~*4.3.1.1 Default Input*~~

Using default values rather than diagnostic procedures produce relatively low air distribution-system efficiencies.Default values shall be obtained from following sections:

1. The location of the duct system in Section 4.3.4,
2. The surface area and insulation level of the ducts in Sections 4.3.3, 4.3.4 and 4.3.6,
3. The system fan flow in Section 4.3.7, and
4. The leakage of the duct system in Section 4.3.7~~8~~.

RF4.3.2 Diagnostic Input

Diagnostic inputs are used for the calculation of improved duct efficiency. The diagnostics include observation of various duct characteristics and measurement of duct leakage and system fan flows as described in Sections 4.3.5 through 4.3.7~~8~~ and ACM RO-2005. These observations and measurements replace those assumed as default values.

The diagnostic procedures include:

- Measure supply duct surface area as described in Section 4.3.3.2.
- Measure total duct system leakage as described in Section 4.3.8.
- ~~measure system fan flow or observe the presence of a thermostatic expansion valve for claiming ACCA manual D design credit as described in Section 4.3.7.~~
- Observe the insulation level for the supply (R_s) and return (R_r) ducts outside the conditioned space as described in Section 4.3.6.
- Observe the presence of radiant barriers.

RF4.3.3 Duct Surface Area

The supply-side and return-side duct surface areas shall be calculated separately. If the supply or return duct is located in more than one zone, the area of that duct in each zone shall be calculated separately. The duct surface area shall be determined using the following methods.

RF 4.3.3.1 Default Duct Surface Area

4.3.3.1.1 Duct Surface Area for More than 12 feet of Duct Outside Conditioned Space

The default duct surface area for supply and return shall be calculated as follows:

For supplies:

$$A_{S,} total = 0.27 \times A_{floor} \qquad \text{Equation RF1}$$

For returns:

$$A_{r,total} = K_r \times A_{floor} \qquad \text{Equation RF2}$$

Where K_r (return duct surface area coefficient) shall be 0.05 for one story building and 0.1 for two or more stories.

4.3.3.1.1 Duct Surface Area for Less Than 12 feet of Duct Outside Conditioned Space

For HVAC systems with air handlers located outside the conditioned space but with less than 12 feet of duct located outside the conditioned space including air handler and plenum, the duct surface area outside the conditioned space shall be calculated as follows:

$$A_{s,out} = 0.027\ A_{floor} \qquad \text{Equation RF3}$$

Where $A_{s,out}$ is substituted for $A_{s,attic}$; $A_{s,crawl}$; or $A_{s,base}$ depending on the location of the ducts.

RF4.3.3.2 Diagnostic Duct Surface Area

A well-designed duct system can reduce the length of the supply duct. Smaller duct surface area will result in reduced duct conduction losses. Duct surface area shall be calculated from measured duct lengths and nominal outside diameters (for round ducts) or outside perimeters (for rectangular ducts) of each duct run in the building. Improved conduction losses can be claimed for reduced supply duct surface area only (it does not apply to the return duct). Supply plenum surface area shall be included in the supply duct surface area. Diagnostic duct surface area requires measuring duct surface areas separately for each location outside conditioned space ($A_{s,attic}$; $A_{s,crawl}$; or $A_{s,base}$) and the system fan flow using the methods in ACM RL-2005 to ensure that there is sufficient air flow to deliver the designed heating and cooling loads, see ACM section 4.28 for criteria.

RF4.3.4 Duct Location

Duct location determines the external temperature for duct conduction losses, the temperature for return leaks, and the thermal regain of duct losses. Default duct surface areas by locations of the supply duct shall be obtained from Table RF1. The default duct surface area for crawlspace and basement applies only to buildings with all supply ducts installed in the crawlspace or basement. If the supply duct is installed in locations other than crawlspace or basement, the default supply duct location shall be "Other".

If ducts are installed in multiple locations, air distribution efficiency shall be calculated for each duct location. Total air distribution efficiency for the house shall be the weighted average based on the floor area served by each duct system.

Table RF1 –Default Assumptions for Duct Locations

	Supply Duct Surface Area		**Return Duct Surface Area**	
Supply or Return Duct Location	One story	Two or more story	One story	Two or more story
Attic	100% attic	65% attic 35% conditioned space	100% attic	100% attic
Crawlspace	100% crawlspace	65% crawlspace 35% conditioned space	100% attic	100% attic
Basement	100% Basement	65% basement 35% conditioned space	100% Basement	100% Basement
Other	100% attic	65% attic 35% conditioned space	100% attic	100% attic

4.3.5 Climate and Duct Ambient Conditions for Ducts Outside Conditioned Space

Duct ambient temperature for both heating and cooling at different duct locations shall be obtained from Table RF2. Indoor dry-bulb (T_{in}) temperature for cooling is 78°F. The indoor dry-bulb temperature for heating is 70°F. Reduction of attic temperature and the reduction in solar radiation effect due to radiant barriers shall only be applied to cooling calculations. The procedures for the installation of radiant barriers shall be as described in ACM Section 4.23. Attic temperatures for houses with radiant barriers shall be obtained from Table RF2.

Table RF2 – Default Assumptions for Duct Ambient Temperature

	Duct Ambient Temperature for Heating, $T_{heat,amb}$			Duct Ambient Temperature for Cooling, $T_{cool,amb}$				
Climate zone	Attic	Crawlspace	Basement	Attic	Attic w/ radiant barrier (supply)	Attic w/ radiant barrier (return)	Crawlspace	Basement
1	52.0	52.2	48.9	60.0	65.4	61.2	54.0	49.1
2	48.0	48.7	56.5	87.0	84.3	84.2	78.0	64.5
3	55.0	54.9	58.3	80.0	79.4	78.2	71.8	62.8
4	53.0	53.1	56.6	79.0	78.7	77.4	70.9	61.4
5	49.0	49.6	52.3	74.0	75.2	73.1	66.4	56.8
6	57.0	56.7	59.9	81.0	80.1	79.1	72.7	64.1
7	62.0	61.1	60.4	74.0	75.2	73.1	66.4	61.6
8	58.0	57.6	60.1	80.0	79.4	78.2	71.8	63.9
9	53.0	53.1	59.6	87.0	84.3	84.2	78.0	66.4
10	53.0	53.1	61.1	91.0	87.1	87.6	81.6	68.9
11	48.0	48.7	59.5	95.0	89.9	91.0	85.1	69.5
12	50.0	50.4	59.3	91.0	87.1	87.6	81.6	67.8
13	48.0	48.7	58.4	92.0	87.8	88.4	82.4	67.6
14	39.0	40.7	55.4	99.0	92.7	94.4	88.7	68.6
15	50.0	50.4	63.4	102.	94.8	96.9	91.3	74.6
16	32.0	34.4	43.9	80.0	79.4	78.2	71.8	54.1

4.3.6 Duct Wall Thermal Resistance

4.3.6.1 Default Duct Insulation R-value

Default duct wall thermal resistance is R4.2. An air film resistance of 0.7 [h ft^2 ^{o}F/BTU] shall be added to the duct insulation R-value to account for external and internal film resistance.

4.3.6.2 Diagnostic Duct Wall Thermal Resistance

Duct wall thermal resistance shall be determined from the manufacturer's specification observed during diagnostic inspection. If ducts with multiple R0values are installed, the lowest duct R-value shall be used. If a duct with a higher R value than 4.2 is installed, the R-value shall be clearly stated on the building plan and a visual inspection of the ducts must be performed to verify the insulation values. In case the space on top of the duct boot is limited and cannot be inspected, the insulation R-value within two feet of the boot to which the duct is connected may be excluded from the determination of the overall system R-value.

4.3.7 ~~System Fan Flow~~

~~4.3.7.1~~ Default System Fan Flow

The default cooling fan flow with an air conditioner and for heating with a heat pump for all climate zones~~climate zones 8 through 15~~ shall be ~~calculated as follows:~~

~~Qe = 0.70 Afloor (4.4)~~ obtained from the ACM calculated Maximum Cooling Size, see ACM section 2.X[1]

1 The air flow for the maximum allowable cooling size is a more reasonable value to base duct leakage testing on than a CFM/ft2 of floor area value.

The default ~~cooling fan flow with an air conditioner and for heating with a heat pump for~~ ~~**climate zones 1 through 7 and 16**~~ ~~and~~ default heating fan flow for forced air furnaces for all climate zones shall be calculated as follows:

$$Q_e = 0.50\ A_{floor} \qquad \text{Equation RF4}$$

~~***4.3.7.2 Diagnostic Fan Flow***~~

~~To obtain duct efficiency credit for duct systems designed according to ACCA Manual D, a diagnostic fan flow measurement must be performed or the installation of a thermostatic expansion valve must be verified. The access panel on the cooling coil shall be removable for the verification of a thermostatic expansion valve. For ACCA Manual D designed duct system, engineering calculations and the building plan for duct sizing and layout shall also be prepared. The diagnostic fan flow measurement shall be measured using one of the following methods:~~

~~***4.3.7.2.1 Diagnostic Fan Flow Using Flow Hood:***~~

~~To measure the system return fan flow, all registers shall be fully open, and the air filter shall be installed. Turn on the system fan and measure the fan flow at the return grille(s) with a calibrated flow hood to determine the total system return fan flow. The system fan flow (Q_e) shall be the sum of the measured return flows.~~

~~***4.3.7.2.2 Diagnostic Fan Flow Using Plenum Pressure Matching:***~~

~~The fan flow measurement shall be performed using the following procedures:~~

1. ~~With the system fan on (in heating mode with burners on for heating, or in cooling mode with compressor on), measure the pressure difference (in pascal) between the supply plenum and the conditioned space (∆ P_{sp}). P_{sp} is the target pressure to be maintained during the fan flow tests. If there is no access to the supply plenum, then place the pressure probe in the nearest supply duct. Adjust the probe to achieve the highest pressure and then firmly attach the probe (e.g., with duct tape) to ensure that it does not move during the fan flow test.~~
2. ~~Block the return duct from the plenum upstream of the air handler fan and the fan flowmeter. Filters are often located in an ideal location for this blockage.~~
3. ~~Attach the fan flowmeter device to the duct system at the air handler. For many air handlers, there will be a removable section that allows access to the fan that is suitable for this purpose. Assure that there is no significant leakage between the fan flowmeter and the system fan.~~
4. ~~If the fan flowmeter is connected to the air handler outside the conditioned space, then the door or access panel between the conditioned space and the air handler location shall be opened.~~
5. ~~Turn on the system fan and the fan flowmeter, adjust the fan flowmeter until the pressure between supply plenum and conditioned space matches P_{sp}.~~
6. ~~Record the flow through the flowmeter (Q_e, cfm) - this is the diagnostic fan flow.~~

~~In some systems, typical system fan and fan flowmeter combinations may not be able to produce enough flow to reach P_{sp}. In this case record the maximum flow (Q_{max}, cfm) and pressure (P_{max}) between the supply plenum and the conditioned space. The following equation shall be used to correct measured system flow and pressure (Q_{max} and P_{max}) to operating condition (Q_e) at operating pressure (P_{sp}).~~

$$\cancel{Q_e = Q_{max}\left(\frac{P_{sp}}{P_{max}}\right)^{\frac{1}{2}} \qquad (4.6)}$$

4.3.8 Duct Leakage

4.3.8.1 Duct Leakage Factor for Delivery Effectiveness Calculations

Default duct leakage factors shall be obtained from Table RF3, using the “not Tested” values.

Duct leakage factors shown in Table RF3 shall be used in calculations of delivery effectiveness.

Table RF3 – Duct Leakage Factors

	Duct Leakage Diagnostic Test Performed using Section 4.3.8.2 Procedures	$a_s = a_r =$
Duct systems in homes built prior to 1999	Not tested	0.86
Duct systems in homes built after 1999	Not tested	0.89
Duct systems in homes of all ages, System with refrigerant based cooling, tested after house and HVAC system completion	(Q_{25}) Total leakage is less than 0.06 Q_{ecool}	0.96
Duct systems in homes of all ages, System without refrigerant based cooling, tested after house and HVAC system completion	(Q_{25}) Total leakage is less than 0.06 Q_{eheat}	0.96
Duct systems with refrigerant based cooling, in homes built after 1999, System tested with air handler installed, but prior to installation of the interior finishing wall	(Q_{25}) Total leakage is less than 0.06 Q_{ecool} and final duct integrity verified	0.96
Duct systems without refrigerant based cooling, in homes built after 1999, System tested with air handler installed, but prior to installation of the interior finishing wall	(Q_{25}) Total leakage is less than 0.06 Q_{eheat} and final duct integrity verified	0.96
Duct systems with refrigerant based cooling, in homes built after 1999, System tested without air handler installed, but prior to installation of the interior finishing wall	(Q_{25}) Total leakage is less than 0.04 Q_{ecool} and final duct integrity verified	0.96
Duct systems without refrigerant based cooling, in homes built after 1999, System tested without air handler installed, but prior to installation of the interior finishing wall	(Q_{25}) Total leakage is less than 0.04 Q_{eheat} and final duct integrity verified	0.96

4.3.8.2 Diagnostic Duct Leakage

Diagnostic duct leakage measurement is used to quantify total leakage for the calculation of air distribution efficiency. To obtain the improved duct efficiency for sealing the duct system, a diagnostic leakage test as described in section 4.3.8.2.1 or 4.3.8.2.2 must be performed. ~~Houses built after 1/1/1999 shall not be allowed to claim duct leakage credit and d~~Diagnostic testing may not be done on any HVAC system that uses building cavities such as plenums or a platform return.

4.3.8.2.1 Diagnostic Duct Leakage from Fan Pressurization of Ducts

The total duct leakage shall be determined by pressurizing the ducts to 25 Pascals. The following procedure shall be used for the fan pressurization tests:

1. Seal all the supply and return registers, except for one return register or the system fan access.
2. Attach the fan flowmeter device to the duct system at the unsealed register or access door.
3. Install a static pressure probe at a supply.
4. Adjust the fan flowmeter to produce a 25 Pascal (0.1 in water) pressure difference between the supply duct and the outside or the building space with the entry door open to the outside.
5. Record the flow through the flowmeter ($Q_{total,25}$) - this is the total duct leakage flow at 25 Pascals.

When the diagnostic leakage test is performed and the measured total duct leakage is less than 6% of the total fan flow, the duct leakage factor shall be 0.96 as shown in Table RF3.

4.3.8.2.2 Diagnostic Duct Leakage at Rough-in Construction Stage Using An Aerosol Sealant Closure System

Duct leakage in new construction may be determined by using diagnostic measurements at the rough-in building construction stage prior to installation of the interior finishing wall when using an aerosol sealant closure system. When using this measurement technique, additional verification (as described in section 4.3.8.2.2.3) of duct integrity shall be completed after the finishing wall has been installed. In addition, after the finishing wall is installed, spaces between the register boots and the wallboard shall be sealed. Cloth backed rubber adhesive duct tapes shall not be used to seal the space between the register boot and the wall board.

The duct leakage measurement at rough-in construction stage shall be performed using a fan pressurization device. The duct leakage shall be determined by pressurizing both the supply and return ducts to 25 Pa. The procedures in Sections 4.3.8.2.2.1 and 4.3.8.2.2.2 shall be used for measuring duct leakage before the interior finishing wall is installed.

4.3.8.2.2.1 For Ducts with the Air Handling Unit Installed and Connected:

For total leakage:

1. Verify that supply and return plenums and all the connectors, transition pieces and duct boots have been installed. If a platform is used as part of the air distribution system, it must contain a duct, and all return connectors and transition parts shall be installed and sealed. The platform, duct and connectors shall be included in the total leakage test.
2. Seal all the supply duct boots and return boxes except for one return duct box.
3. Attach the fan flowmeter device at the unsealed duct box.
4. Insert a static pressure probe at one of the sealed supply duct boots.
5. Adjust the fan flowmeter to maintain 25 Pa (0.1 in water) between the duct system and outside or the building space with the entry door open to the outside.
6. Record the air flow through the flowmeter ($Q_{total,25}$) - This is the total duct leakage at 25 Pa at rough-in stage.
7. Divide the measured total leakage by the total fan flow calculated from Equation RF4 or RF5.

If the total leakage is less than 6% of the total fan flow, the duct leakage factor shall be 0.96 as shown in Table RF3.

4.3.8.2.2.2 For Ducts with Air Handling Unit Not Yet Installed:

For total leakage:

1. Verify that all the connectors, transition pieces and duct boots have been installed. If a platform is used as part of the air distribution system, it must contain a duct, and all return connectors and transition parts shall be installed and sealed. The platform, duct and connectors shall be included in the total leakage test.
2. Use a duct connector to connect supply and/or return duct box to the fan flowmeter. Supply and return leaks may be tested separately. If there is only one return register, the supply and return leaks shall be tested at the same time.
3. Seal all the supply duct boots and/or return boxes except for one supply or return duct box.
4. Attach the fan flowmeter device at the unsealed duct box.
5. Insert a static pressure probe at one of the sealed supply duct boots.
6. Adjust the fan flowmeter to maintain 25 Pa (0.1 in water) between the building conditioned space and the duct system.
7. Record the air flow through the flowmeter ($Q_{total,25}$) - This is the total duct leakage at 25 Pa.

8. Divide the measured total leakage by the total fan flow calculated from Equation RF4 or RF5. If the total leakage is less than 4% of the total fan flow, the total duct leakage factor shall be 0.96 as shown in Table RF3.

4.3.8.2.2.3 Post Rough-in Duct Leakage Verification

After installing the interior finishing wall and verifying that one of the above rough-in tests was completed, one of the following post rough-in verification tests shall be performed to ensure that there is no major leakage in the duct system.

4.3.8.2.2.3.1 Visual Inspection

Remove at least one supply and one return register to verify that the spaces between the register boot and the interior finishing wall are properly sealed. In addition, if the house rough-in duct leakage test was conducted without an air handler installed, inspect the connection points between the air handler and the supply and return plenums to verify that the connection points are properly sealed. All joints shall be inspected to ensure that no cloth backed rubber adhesive duct tape is used.

4.3.8.2.2.3.2 Pressure Pan Test

With register dampers fully open, the house is pressurized to 25 pascals by a blower door, (if two registers are within 5 feet of each other and are connected to the same duct run, one register shall be sealed off before the pressure pan test is performed). The pressure difference across each register shall not exceed 1.5 Pa.

4.3.8.2.2.3.3 House Pressure Test

The pressure difference between the building conditioned space and a vented attic shall be measured to determine whether the house pressure is changed appreciably by the operation of the air handler. To perform this test, the pressure difference (P_{house}- P_{out}) between the building conditioned space and a vented attic (or outside if impossible to access the attic), shall be measured four times:

1. With the fan off (ΔP_{off1})
2. With the fan on (ΔP_{on})
3. With the fan on and the return grille 80% blocked (ΔP_{RB}). Block 80% on all return grilles if the house has two or more returns.
4. With the fan off (ΔP_{off2})

For each of these measurements, the five-second average pressure shall be measured 10 times and these 10 measurements shall be averaged.

For the house to pass this test, the following conditions must be true:

1. ΔP_{on} -(Δ P_{off2}+ΔP_{off1})/2 must be between +0.8 Pa and -0.8 Pa and
2. ΔP_{RB} -ΔP_{on} must be less than 0.8 Pa.

In addition, the absolute value of (Δ P_{off2} -ΔP_{off1}) must be less than 0.25 Pa, or else the test must be repeated. If the repeated test does not meet the above specified values, visual inspection or the pressure pan test or the fan pressurization test must be used. If these tests fail, the duct system needs to be properly sealed and re-verified by a fan pressurization test.

4.4 Delivery Effectiveness (DE) Calculations

Seasonal delivery effectiveness shall be calculated using the seasonal design temperatures from Tables RF2.

4.4.1 Calculation of Duct Zone Temperatures

The temperatures of the duct zones outside the conditioned space are determined in Section 4.3.5 for seasonal conditions for both heating and cooling. If the ducts are not all in the same location, the duct ambient temperature for use in the delivery effectiveness and distribution system efficiency calculations shall be determined using an area weighted average of the duct zone temperatures:

$$T_{amb,s} = \frac{(A_{s,attic} + 0.001)T_{attic} + A_{s,crawl} \times T_{crawl} + A_{s,base} \times T_{base}}{A_{s,out} + 0.001} \qquad \text{Equation RF5}$$

$$T_{amb,r} = \frac{A_{r,attic}\ T_{attic} + A_{r,crawl} \times T_{crawl} + A_{r,base} \times T_{base}}{A_{r,out}} \qquad \text{Equation RF6}$$

The return ambient temperature, $T_{amb,r}$, shall be limited as follows:

For heating, the maximum $T_{amb,r}$ is $T_{in,heat}$. For cooling, the minimum $T_{amb,r}$ is $T_{in,cool}$.

$$T_{amb,r} = \frac{T_{design} - 16\,^{o}F + \dfrac{\displaystyle\sum_{i=\text{duct location}}^{\substack{\text{all return duct locations}\\ \text{outside conditioned space}}} A_i\, T_i}{A_r}}{2} \qquad (4.20b)$$

4.4.2 Seasonal Delivery Effectiveness (DE)

The supply and return conduction fractions, B_s and B_r, shall be calculated as follows:

$$B_s = \exp\left(\frac{-A_{s,out}}{1.08 Q_e \times R_s}\right) \qquad \text{Equation RF7}$$

$$B_r = \exp\left(\frac{-A_{r,out}}{1.08 Q_e \times R_r}\right) \qquad \text{Equation RF8}$$

The temperature difference across the heat exchanger in the following equation is used:

for heating:

$$\Delta T_e = 55 \qquad \text{Equation RF9}$$

for cooling:

$$\Delta T_e = -20 \qquad \text{Equation RF10}$$

The temperature difference between the building conditioned space and the ambient temperature surrounding the supply, ΔT_s, and return, ΔT_r, shall be calculated using the indoor and the duct ambient temperatures.

$$\Delta T_s = T_{in} - T_{amb,s} \qquad \text{Equation RF11}$$

$$\Delta T_r = T_{in} - T_{amb,r} \qquad \text{Equation RF12}$$

The seasonal delivery effectiveness for heating or cooling systems shall be calculated using:

$$DE_{seasonal} = a_s B_s - a_s B_s (1 - B_r a_r) \frac{\Delta T_r}{\Delta T_e} - a_s (1 - B_s) \frac{\Delta T_s}{\Delta T_e}$$ Equation RF13

4.5 Seasonal Distribution System Efficiency

Seasonal distribution system efficiency shall be calculated using delivery effectiveness, equipment, load, and recovery factors calculated for seasonal conditions.

~~4.5.1 Equipment Efficiency Factor (F_{equip})~~

~~Equipment efficiency factor accounts for interactions between the duct system and the operation of the heating or cooling equipment. If the duct size and layout are designed and installed according to ACCA manual D and if the fan flow measurement meets the design specifications, the efficiency factor for F_{equip} is 1. Otherwise F_{equip} shall be 0.925. For heating, F_{equip} is 1.~~

[2]

4.5.2 Thermal Regain (F_{regain})

The reduction in building load due to regain of duct losses shall be calculated using the thermal regain factor. The default thermal regain factors are provided in Table RF4.

Table RF4 – Thermal Regain Factors

Supply Duct Location	Thermal Regain Factor [F_{regain}]
Attic	0.10
Crawlspace	0.12
Basement	0.30
Other	0.10

4.5.3 Recovery Factor (F_{recov})

The recovery factor, F_{recov}, is calculated based on the thermal regain factor, F_{regain}, and the duct losses without return leakage.

$$F_{recov} = 1 + F_{regain} \left(\frac{1 - a_s B_s + a_s B_s (1 - B_r) \frac{\Delta T_r}{\Delta T_e} + a_s (1 - B_s) \frac{\Delta T_s}{\Delta T_e}}{DE_{seasonal}} \right)$$ Equation RF14

4.5.4 Seasonal Distribution System Efficiency

The seasonal distribution system efficiency shall be calculated using the seasonal delivery effectiveness from Section 4.4.2, the equipment efficiency factor from Section 4.5.1 and the thermal recovery factor from Section 4.5.3. Note that $DE_{seasonal}$, ~~F_{equip},~~ F_{recov} must be calculated separately for cooling and heating conditions. Distribution system efficiency shall be determined using the following equation:

$$\eta_{dist,seasonal} = 0.98\, DE_{seasonal} \times F_{recov}$$ Equation RF15

[2] F_{equip} is now included in F_{air} . See ACM Section 4.28.

where 0.98 accounts for the energy losses from heating and cooling the duct thermal mass.

4.6 Hourly Attic Duct Efficiency for ACM Calculations[3]

The algorithm in this ACM appendix shall be used to model the hourly variation in duct efficiency for ducts located in attics.

4.6.1 Purpose

The hourly duct efficiency multiplier for ducts in attics shall be calculated for each hour using equation P.1

DEMhr = $DE_{season//}DE_{hr}$ Equation RF16

For ducts in other locations the hourly duct efficiency shall be 1 for all hours.

4.6.2 Nomenclature

DE_{hr}	hourly distribution system efficiency
DE_{season}	seasonal average distribution system efficiency
E_{hr}	hourly HVAC system energy use
$E_{ideal,hr}$	hourly HVAC system energy use for ideal duct system with no losses
T_{solair}	sol-air temperature, °C
T_{in}	indoor air dry-bulb temperature, °C
T_{amb}	outdoor air dry-bulb temperature, °C
ΔT_{sky}	reduction of sol-air temperature due to sky radiation, = 3.6°C
I_{hor}	global solar radiation on horizontal surface, kJ/hr m^2
α	solar absorptivity of roof = 0.50
h_o	outside surface convection coefficient, = 70 kJ/hr m^2°C
$\Delta T_{sol,season}$	energy weighted seasonal average difference between sol-air and indoor temperatures
R_{duct}	duct insulation R-value, hr ft^2°F/Btu
L_{duct}	duct leakage as fraction of supply airflow, dimensionless
C_{DT}, C_0, C_R, C_L	regression coefficients

$$\frac{DE_{season}}{DE_{hr}} = 1 + C_{DT} \times \left(\frac{\Delta T_{sol,hr}}{\Delta T_{sol,season}} - 1 \right) \qquad \text{Equation RF17}$$

$$\Delta T_{sol,hr} = T_{solair,hr} - T_{in,hr} \qquad \text{Equation RF18}$$

$$\Delta_{Tol,season} = \sum_{season} \frac{(T_{solair,hr} - T_{in,hr})E_{hr}}{\sum_{season} E_{hr}} \qquad \text{Equation RF19}$$

3 Wilcox, B and Brandemuhl, M, “Hourly Attic Duct Efficiency Model for California Homes”, PG&E TDV project 2002.

$$T_{solair,hr} = T_{amb,hr} + \left(\frac{\alpha}{h_o}\right) I_{hor,hr} - \Delta T_{sky} \quad \text{Equation RF20}$$

$$DE_{hr} = \frac{E_{ideal,hr}}{E_{hr}} \quad \text{Equation RF21}$$

$$C_{DT} = C_0 + {C_R}/{R_{duct}} + C_L L_{duct} \quad \text{Equation RF22}$$

4.6.3 Coefficients and Data

TableRF5 – Coefficients

	Cooling	Cooling	Heating	Heating
	Radiant Barrier	No Radiant Barrier	Radiant Barrier	No Radiant Barrier
C_0	0.0078	0.0186	0.0350	0.0205
C_R	0.1222	0.0877	0.0794	0.1202
C_L	0.5480	0.2995	0.0714	0.2655

Table RF6 – Seasonal Sol-Air Temperature Difference, °F

Climate Zone	Cooling	Heating
1	23.00	-20.01
2	31.69	-23.64
3	23.66	-18.90
4	26.29	-21.13
5	26.02	-20.25
6	23.79	-17.12
7	25.17	-17.16
8	30.89	-19.46
9	32.73	-18.85
10	33.34	-21.53
11	34.24	-24.38
12	34.65	-23.31
13	34.53	-22.92
14	35.29	-25.64
15	33.33	-20.32
16	29.43	-29.86

Appendix RK – Procedures for Determining ~~Required~~ Refrigerant Charge ~~and Adequate Airflow~~ for Split System Space Cooling Systems without Thermostatic Expansion Valves

RK1. Purpose and Scope~~Overview~~

~~Failure to maintain proper refrigerant charge or proper airflow across the coil reduces the seasonal energy efficiency for an air conditioner (whether a cooling only air conditioner or a heat pump). In addition, excessive refrigerant charge can cause premature compressor failure, while insufficient refrigerant charge allows compressors to overheat. Very low airflow can result in icing of the coil and compressor failure.~~

~~To help avoid these problems and to provide a compliance credit for correctly installed systems,~~ The purpose of this ~~this appendix describes~~ procedures is to verify that ~~for determining if a~~ residential split system space cooling systems and heat pumps have ~~has~~ the required refrigerant charge ~~and adequate airflow across the evaporator coil~~. The ~~applicability of these~~ procedures ~~have the following limitations: The procedures detailed in this appendix~~ only apply to ducted split system central air conditioners and ducted split system central heat pumps that do not have thermostatic expansion valves (TXVs). ~~As an alternative to the procedures detailed in this appendix, systems may substitute a TXV installed and confirmed through field verification and diagnostic testing.~~ The procedures ~~detailed in this appendix~~ do not apply to ~~single~~ packaged systems. For dwelling units with multiple split systems or heat pumps, the procedure must be applied to each system separately.

~~Note that t~~The procedures detailed in ~~this appendix~~ ACM RK are intended to be used after the HVAC installer has installed and charged the air conditioner or heat pump system in accordance with the ~~manufacturer's specifications. The installer shall install and charge the air conditioner and heat pump equipment in accordance with the~~ manufacturer's instructions and specifications for the specific model equipment installed. The installer shall certify to the builder, building official and HERS rater that ~~they have~~ it has followed ~~these~~ manufacturer's instruction and specifications prior to proceeding with the procedures in this appendix.

A~~For dwelling units with multiple systems, this procedure must be applied to each system separately.~~

~~This appendix~~ CM RK defines two procedures, the Standard Charge ~~and Airflow~~ Measurement P~~procedure~~ rocedure in Section 2 and the Alternate Charge ~~and Airflow~~ Measurement P~~p~~rocedure in Section 3. The Standard procedure shall be used when the outdoor air temperature is 55°F or above and shall always be used for HERS rater verification. HVAC installers who must complete system installation when the outdoor temperature is below 55°F shall use the Alternate procedure.

The following sections document the instrumentation needed, the required instrumentation calibration, the measurement procedure, and the calculations required for each procedure. Note: Wherever thermocouples appear in this document, thermisters can be used instead with the same requirements applying to thermisters as to thermocouples.

RK2. Standard Charge ~~and Airflow~~ Measurement Procedure

This section specifies the Standard charge ~~and airflow~~ measurement procedure. Under this procedure, required refrigerant charge is calculated using the *Superheat Charging Method*. ~~and~~ The method also checks ~~adequate~~ airflow across the evaporator coil ~~is~~ to determine whether the charge test is valid ~~calculated~~ using the *Temperature Split Method* or the air flow measurement methods in Appendix X.

The Standard procedure detailed in this section shall be completed when the outdoor temperature is 55°F or higher after the HVAC installer has installed and charged the system in accordance with the manufacturer's specifications. If the outdoor temperature is between 55°F and 65°F the return dry bulb temperature shall be maintained above 70°F during the test. All HERS rater verifications are required to use this Standard procedure.

RK2.1 Minimum Qualifications for this Procedure

Persons carrying out this procedure need to be qualified to perform the following:

- Obtain accurate pressure/temperature readings from refrigeration manifold gauges.
- Obtain accurate temperature readings from thermometer and thermocouple set up.
- Check calibration of refrigerant gauges using a known reference pressure and thermometer/thermocouple set up using a known reference temperature.
- Determine best location for temperature measurements in ducting system and on refrigerant line set.
- Calculate the measured superheat and temperature split.
- Determine the correct level of superheat and temperature split required, based on the conditions present at the time of the test.
- Determine if measured values are reasonable.

RK2.2 Instrumentation Specifications

Instrumentation for the procedures described in this section shall conform to the following specifications:

RK2.2.1 Digital Thermometer

Digital thermometer must have thermocouple compatibility (type K and J) and Celsius or Fahrenheit readout with:

- Accuracy: ±(0.1% of reading + 1.3º F).
- Resolution: 0.2º F.

RK2.2.2 Thermocouples

Measurements require five (5) heavy duty beaded low-mass wire thermocouples and one (1) cotton wick for measuring wet-bulb temperatures.

RK2.2.3 Refrigerant Manifold Gauge Set

A standard multiport refrigerant manifold gauge with an accuracy of plus or minus 3% shall be used.

RK2.3 Calibration

The accuracy of instrumentation shall be maintained using the following procedures. A sticker with the calibration check date shall be affixed to each instrument calibrated.

RK2.3.1 Thermometer/Thermocouple Field Calibration Procedure

Thermometers/thermocouples shall be calibrated monthly to ensure that they are reading accurate temperatures. The following procedure shall be used to check thermometer/thermocouple calibration:

1. Fill an insulated cup (foam) with crushed ice. The ice shall completely fill the cup. Add water to fill the cup.
2. Insert two thermocouples into the center of the ice bath and attach them to the digital thermometer.
3. Let the temperatures stabilize. The temperatures shall be 32°F (+/- 1°F). If the temperature is off by more than 1°F make corrections according to the manufacturer's instructions. Any thermocouples that are off by more than 3°F shall be replaced.

4. Switch the thermocouples and ensure that the temperatures read on T1 and T2 are still within +/- 1°F of 32°F.
5. Affix sticker with calibration check date onto thermocouple.
6. Repeat the process for all thermocouples.

RK2.3.2 Refrigerant Gauge Field Check Procedure

Refrigerant gauges shall be checked monthly to ensure that the gauges are reading the correct pressures and corresponding temperatures. The following procedure shall be used to check gauge calibration:

1. Place a refrigerant cylinder in a stable environment and let it sit for 4 hours minimum to stabilize to the ambient conditions.
2. Attach a thermocouple to the refrigerant cylinder using duct tape so that there is good contact between the cylinder and the thermocouple.
3. Insulate the thermocouple connection to the cylinder (closed cell pipe insulation can be taped over the end of the thermocouple to provide the insulation).
4. Zero the low side compound gauge with all ports open to atmospheric pressure (no hoses attached).
5. Re-install the hose and attach the low side gauge to the refrigerant cylinder.
6. Read the temperature of the thermocouple.
7. Using a pressure/temperature chart for the refrigerant, look up the pressure that corresponds to the temperature measured.
8. If gauge does not read the correct pressure corresponding to the temperature, the gauge is out of calibration and needs to be replaced or returned to the manufacturer for calibration.
9. Repeat the process in steps 4 through 8 for the high side gauge.
10. Affix sticker with calibration check date onto refrigerant gauge.

RK2.4 Charge ~~and Airflow~~ Measurements

The following procedure shall be used to obtain measurements necessary to adjust required refrigerant charge ~~and adequate airflow~~ as described in the following sections:

~~Step 1.~~1. If the condensor air entering temperature is less than 65°F, ~~E~~establish a return air dry bulb temperature sufficiently high that the return air dry bulb temperature will be not less than 70°F prior to the measurements at the end of the 15 minute period in step 2.
2. Turn the cooling system on and let it run for 15 minutes to stabilize temperatures and pressures before taking any measurements. While the system is stabilizing, proceed with setting up the temperature measurements.
3. Connect the refrigerant gauge manifold to the suction line service valve.
4. Attach a thermocouple to the suction line near the suction line service valve. Be sure the sensor is in direct contact with the line and is well insulated from air temperature.
5. Attach a thermocouple to measure the condenser (entering) air dry-bulb temperature. The sensor shall be placed so that it records the average condenser air entering temperature and is shaded from direct sun.
6. Be sure that all cabinet panels that affect airflow are in place before making measurements. The thermocouple sensors shall remain attached to the system until the final charge is determined.
7. Place wet-bulb thermocouple in water to ensure it is saturated when needed. **Do not get the dry-bulb thermocouples wet.**
8. Insert the dry-bulb thermocouple in the supply plenum at the center of the airflow.

9. At 12 minutes, insert a dry-bulb thermocouple and a wet-bulb thermocouple into the return plenum at the center of the airflow.
10. At 15 minutes when the return plenum temperatures have stabilized, using the thermocouples already in place, measure and record the return (evaporator entering) air dry-bulb temperature ($T_{return, db}$) and the return (evaporator entering) air wet-bulb temperature ($T_{return, wb}$).
11. Using the dry-bulb thermocouple already in place, measure and record the supply (evaporator leaving) air dry-bulb temperature ($T_{supply, db}$).
12. Using the refrigerant gauge already attached, measure and record the evaporator saturation temperature ($T_{evaporator, sat}$) from the low side gauge.
13. Using the dry-bulb thermocouple already in place, measure and record the suction line temperature ($T_{suction, db}$).
14. Using the dry-bulb thermocouple already in place, measure and record the condenser (entering) air dry-bulb temperature ($T_{condenser, db}$).

The above measurements shall be used to adjust refrigerant charge and airflow as described in following sections.

RK2.5 Refrigerant Charge Calculations

The Superheat Charging Method is used only for non-TXV systems equipped with fixed metering devices. These include capillary tubes and piston-type metering devices. The following steps describe the calculations to determine if the system meets the required refrigerant charge using the measurements described in section 2.4. If a system fails, then remedial actions must be taken. If the refrigerant charge is changed and the airflow has been previously tested and shown to pass, then the airflow shall be re-tested. Be sure to complete Steps 1 and 2 of Section 2.4 before re-testing the airflow. Both the airflow and charge must be re-tested until they both sequentially pass.

1. Calculate Actual Superheat as the suction line temperature minus the evaporator saturation temperature.

   Actual Superheat = $T_{suction, db} – T_{evaporator, sat}$.

2. Determine the Target Superheat using Table RK-1 using the return air wet-bulb temperature ($T_{return, wb}$) and condenser air dry-bulb temperature ($T_{condenser, db}$).
3. If a dash mark is read from Table RK-1, the target superheat is less than 5°F, then the system **does not pass** the required refrigerant charge criteria, usually because outdoor conditions are too hot and dry. One of the following adjustments is needed until a target superheat value can be obtained from Table RK-1 by either 1) turning on the space heating system and/or opening the windows to warm up indoor temperature; or 2) retest at another time when conditions are different. After adjustments, repeat the measurement procedure as often as necessary to establish the target superheat. Allow system to stabilize for 15 minutes before completing the measurement procedure again.
4. Calculate the difference between actual superheat and target superheat (Actual Superheat - Target Superheat)
5. If the difference is between minus 5 and plus 5°F, then the system **passes** the required refrigerant charge criteria.
6. If the difference is greater than plus 5°F, then the system **does not pass** the required refrigerant charge criteria and the installer shall add refrigerant. After the refrigerant has been added, turn the system on and allow it to stabilize for 15 minutes before completing the measurement procedure again. Adjust refrigerant charge and repeat the measurement procedure as many times as necessary to pass the test.
7. If the difference is between –5 and -100°F, then the system **does not pass** the required refrigerant charge criteria, the installer shall remove refrigerant. After the refrigerant has been removed, turn the system on and allow it to stabilize for 15 minutes before completing the measurement procedure again. Adjust refrigerant charge and repeat the measurement as many times as necessary to pass the test.

RK2.6 ~~Adequate~~ Airflow ~~Calculations~~Verification

In order to have a valid charge test, the air flow must be verified by either passing the temperature split test or by one of the three measurements in ACM RO with a measured airflow in excess of 0.033 cfm/Btu capacity rated at DOE A test conditions (400 cfm/12000 Btu) (dry coil).

The temperature split test method is designed to provide an efficient check to see if airflow is above the required minimum for a valid refrigerant charge test. The following steps describe the calculations using the measurement procedure described in section 2.4. If a system fails, then remedial actions must be taken. If the airflow is changed and the refrigerant charge has previously been tested and shown to pass, then the refrigerant charge shall be re-tested. Be sure to complete Steps 1 and 2 of Section 2.4 before re-testing the refrigerant charge. Both the airflow and charge must be re-tested until they both sequentially pass.

1. Calculate the Actual Temperature Split as the return air dry-bulb temperature minus the supply air dry-bulb temperature. Actual Temperature Split = $T_{return, db}$ - $T_{supply, db}$
2. Determine the Target Temperature Split from Table RK-2 using the return air wet-bulb temperature ($T_{return, wb}$) and return air dry-bulb temperature ($T_{return, db}$).
3. If a dash mark is read from Table RK-2, then there probably was an error in the measurements because the conditions in this part of the table would be extremely unusual. If this happens, re-measure the temperatures. If re-measurement results in a dash mark, complete one of the alternate airflow measurements in Section 3.4 below.
4. Calculate the difference between target and actual temperature split (Actual Temperature Split-Target Temperature Split). If the difference is within plus 3°F and minus 3°F, then the system **passes** the adequate airflow criteria.
5. If the difference is greater than plus 3°F, then the system **does not pass** the adequate airflow criteria and the airflow shall be increased by the installer. Increasing airflow can be accomplished by eliminating restrictions in the duct system, increasing blower speed, cleaning filters, or opening registers. After corrective measures are taken, repeat measurement procedure as often as necessary to establish adequate airflow range. Allow system to stabilize for 15 minutes before repeating measurement procedure.
6. If the difference is between minus 3°F and minus 100°F, then the measurement procedure shall be repeated making sure that temperatures are measured at the center of the airflow.
7. If the re-measured difference is between plus 3°F and minus 3°F the system **passes** the adequate airflow criteria. If the re-measured difference is between minus 3°F and minus 100°F, the system passes, but it is likely that the capacity is low on this system (it is possible, but unlikely, that airflow is higher than average).

RK3. Alternate Charge ~~and Airflow~~ Measurement Procedure

This section specifies the Alternate charge ~~and airflow~~ measurement procedure. Under this procedure, the required refrigerant charge is calculated using the *Weigh-In Charging Method*.

~~and adequate airflow across the evaporator coil is calculated using the Measured Airflow Method.~~

HVAC installers who must complete system installation verification when the outdoor temperature is below 55°F shall use this Alternate procedure in conjunction with installing and charging the system in accordance with the manufacturer's specifications. HERS Raters shall not use this procedure to verify compliance.

Split system air conditioners come from the factory already charged with the standard charge indicated on the name plate. The manufacturer supplies the charge proper for the application based on their standard liquid line length. It is the responsibility of the HVAC installer to ensure that the charge is correct for each air conditioner and to adjust the charge based on liquid line length different from the manufacturer's standard.

RK3.1 Minimum Qualifications for this Procedure

HVAC installation technicians need to be qualified to perform the following:

1. Transfer and recovery of refrigerant (including a valid Environmental Protection Agency (EPA) certification for transition and recovery of refrigerant).
2. Accurately weigh the amount of refrigerant added or removed using an electronic scale.
3. Calculate the refrigerant charge adjustment needed to compensate for non-standard lineset lengths/diameters based on the actual lineset length/diameter and the manufacturer's specifications for adjusting refrigerant charge for non-standard lineset lengths/diameters.

RK3.2 Instrumentation Specifications

~~Instrumentation for the procedures described in this section shall conform to the following specifications.~~

~~*3.2.1 Digital Charging Scale*~~

The digital scale used to weigh in refrigerant must have a range of .5 oz to at least 1200 oz (75 lb.). The scale's accuracy must be ± 0.25 oz.

RK3.3 Weigh-In Method

The following procedure shall be used by the HVAC installer to charge the system with the correct refrigerant charge.

1. Obtain manufacturer's standard liquid line length and charge adjustment for alternate liquid line lengths.
2. Measure and record the actual liquid line length (L_{actual}).
3. Record the manufacturer's standard liquid line length ($L_{standard}$).
4. Calculate the difference between actual and standard liquid line lengths

   (L_{actual} - $L_{standard}$).
5. Record the manufacturer's adjustment for liquid line length difference per foot (A_{length}).
6. Calculate the amount of refrigerant to add or remove and document the calculations on the CF-6R.
7. Weigh in or remove the correct amount of refrigerant

~~3.4 Airflow Measurement~~

~~The airflow across the indoor evaporator coil shall be measured using one of the 2 methods described Appendix F - Standard Procedure for Determining the Seasonal Energy Efficiencies of Residential Air Distribution Systems:~~

~~Section 4.3.7.2.1 Diagnostic Fan Flow Using Flow Hood~~

~~Section 4.3.7.2.2 Diagnostic Fan Flow Using Plenum Pressure Matching~~

~~3.5 Adequate Airflow Calculation~~

~~The measured airflow method is used to provide a check to see if airflow is above the required minimum of 385 CFM per nominal ton of capacity (assumes coil is dry). The following steps describe the calculations using the measurement procedure described in Section 3.4. If a system fails, then remedial actions must be taken. The airflow must be re-tested until it passes.~~

~~Step 1.Record the measured airflow ($F_{measured}$) obtained from the measurement procedures described in Section 3.4.~~

~~Step 2.Obtain and record the rated cooling capacity ($C_{cooling}$) in Btu.~~

~~Step 3.Calculate the required airflow as the product of the rated cooling capacity in Btu times 0.032.~~

~~Step 4.Compare the airflow measured according to section 3.4 with the required airflow.~~

~~Step 5.If the measured airflow is greater than the required airflow, then the system **passes** the adequate airflow criteria.~~

~~Step 6.If the measured airflow is less than the required airflow, the system does not pass the adequate airflow criteria and the airflow shall be increased by the installer. Increasing airflow can be accomplished by eliminating restrictions in the duct system, increasing blower speed, cleaning filters, or opening registers. After corrective measures are taken, repeat measurement procedure.~~

Table RK-1: Target Superheat (Suction Line Temperature - Evaporator Saturation Temperature)

Condenser Air Dry-Bulb Temperature (°F)	Return Air Wet-Bulb Temperature (°F) ($T_{return, wb}$)																										
	50	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67	68	69	70	71	72	73	74	75	76
55	8.8	10.1	11.5	12.8	14.2	15.6	17.1	18.5	20.0	21.5	23.1	24.6	26.2	27.8	29.4	31.0	32.4	33.8	35.1	36.4	37.7	39.0	40.2	41.5	42.7	43.9	45.0
56	8.6	9.9	11.2	12.6	14.0	15.4	16.8	18.2	19.7	21.2	22.7	24.2	25.7	27.3	28.9	30.5	31.8	33.2	34.6	35.9	37.2	38.5	39.7	41.0	42.2	43.4	44.6
57	8.3	9.6	11.0	12.3	13.7	15.1	16.5	17.9	19.4	20.8	22.3	23.8	25.3	26.8	28.3	29.9	31.3	32.6	34.0	35.3	36.7	38.0	39.2	40.5	41.7	43.0	44.2
58	7.9	9.3	10.6	12.0	13.4	14.8	16.2	17.6	19.0	20.4	21.9	23.3	24.8	26.3	27.8	29.3	30.7	32.1	33.5	34.8	36.1	37.5	38.7	40.0	41.3	42.5	43.7
59	7.5	8.9	10.2	11.6	13.0	14.4	15.8	17.2	18.6	20.0	21.4	22.9	24.3	25.7	27.2	28.7	30.1	31.5	32.9	34.3	35.6	36.9	38.3	39.5	40.8	42.1	43.3
60	7.0	8.4	9.8	11.2	12.6	14.0	15.4	16.8	18.2	19.6	21.0	22.4	23.8	25.2	26.6	28.1	29.6	31.0	32.4	33.7	35.1	36.4	37.8	39.1	40.4	41.6	42.9
61	6.5	7.9	9.3	10.7	12.1	13.5	14.9	16.3	17.7	19.1	20.5	21.9	23.3	24.7	26.1	27.5	29.0	30.4	31.8	33.2	34.6	35.9	37.3	38.6	39.9	41.2	42.4
62	6.0	7.4	8.8	10.2	11.7	13.1	14.5	15.9	17.3	18.7	20.1	21.4	22.8	24.2	25.5	27.0	28.4	29.9	31.3	32.7	34.1	35.4	36.8	38.1	39.4	40.7	42.0
63	5.3	6.8	8.3	9.7	11.1	12.6	14.0	15.4	16.8	18.2	19.6	20.9	22.3	23.6	25.0	26.4	27.8	29.3	30.7	32.2	33.6	34.9	36.3	37.7	39.0	40.3	41.6
64	-	6.1	7.6	9.1	10.6	12.0	13.5	14.9	16.3	17.7	19.0	20.4	21.7	23.1	24.4	25.8	27.3	28.7	30.2	31.6	33.0	34.4	35.8	37.2	38.5	39.9	41.2
65	-	5.4	7.0	8.5	10.0	11.5	12.9	14.3	15.8	17.1	18.5	19.9	21.2	22.5	23.8	25.2	26.7	28.2	29.7	31.1	32.5	33.9	35.3	36.7	38.1	39.4	40.8
66	-		6.3	7.8	9.3	10.8	12.3	13.8	15.2	16.6	18.0	19.3	20.7	22.0	23.2	24.6	26.1	27.6	29.1	30.6	32.0	33.4	34.9	36.3	37.6	39.0	40.4
67	-	-	5.5	7.1	8.7	10.2	11.7	13.2	14.6	16.0	17.4	18.8	20.1	21.4	22.7	24.1	25.6	27.1	28.6	30.1	31.5	33.0	34.4	35.8	37.2	38.6	39.9
68	-	-	-	6.3	8.0	9.5	11.1	12.6	14.0	15.5	16.8	18.2	19.5	20.8	22.1	23.5	25.0	26.5	28.0	29.5	31.0	32.5	33.9	35.3	36.8	38.1	39.5
69	-	-	-	5.5	7.2	8.8	10.4	11.9	13.4	14.8	16.3	17.6	19.0	20.3	21.5	22.9	24.4	26.0	27.5	29.0	30.5	32.0	33.4	34.9	36.3	37.7	39.1
70	-	-	-	-	6.4	8.1	9.7	11.2	12.7	14.2	15.7	17.0	18.4	19.7	20.9	22.3	23.9	25.4	27.0	28.5	30.0	31.5	33.0	34.4	35.9	37.3	38.7
71	-	-	-	-	5.6	7.3	8.9	10.5	12.1	13.6	15.0	16.4	17.8	19.1	20.3	21.7	23.3	24.9	26.4	28.0	29.5	31.0	32.5	34.0	35.4	36.9	38.3
72	-	-	-	-	-	6.4	8.1	9.8	11.4	12.9	14.4	15.8	17.2	18.5	19.7	21.2	22.8	24.3	25.9	27.4	29.0	30.5	32.0	33.5	35.0	36.5	37.9
73	-	-	-	-	-	5.6	7.3	9.0	10.7	12.2	13.7	15.2	16.6	17.9	19.2	20.6	22.2	23.8	25.4	26.9	28.5	30.0	31.5	33.1	34.6	36.0	37.5
74	-	-	-	-	-	-	6.5	8.2	9.9	11.5	13.1	14.5	15.9	17.3	18.6	20.0	21.6	23.2	24.8	26.4	28.0	29.5	31.1	32.6	34.1	35.6	37.1
75	-	-	-	-	-	-	5.6	7.4	9.2	10.8	12.4	13.9	15.3	16.7	18.0	19.4	21.1	22.7	24.3	25.9	27.5	29.1	30.6	32.2	33.7	35.2	36.7
76	-	-	-	-	-	-	-	6.6	8.4	10.1	11.7	13.2	14.7	16.1	17.4	18.9	20.5	22.1	23.8	25.4	27.0	28.6	30.1	31.7	33.3	34.8	36.3
77	-	-	-	-	-	-	-	5.7	7.5	9.3	11.0	12.5	14.0	15.4	16.8	18.3	20.0	21.6	23.2	24.9	26.5	28.1	29.7	31.3	32.8	34.4	36.0
78	-	-	-	-	-	-	-	-	6.7	8.5	10.2	11.8	13.4	14.8	16.2	17.7	19.4	21.1	22.7	24.4	26.0	27.6	29.2	30.8	32.4	34.0	35.6
79	-	-	-	-	-	-	-	-	5.9	7.7	9.5	11.1	12.7	14.2	15.6	17.1	18.8	20.5	22.2	23.8	25.5	27.1	28.8	30.4	32.0	33.6	35.2
80	-	-	-	-	-	-	-	-	-	6.9	8.7	10.4	12.0	13.5	15.0	16.6	18.3	20.0	21.7	23.3	25.0	26.7	28.3	29.9	31.6	33.2	34.8
81	-	-	-	-	-	-	-	-	-	6.0	7.9	9.7	11.3	12.9	14.3	16.0	17.7	19.4	21.1	22.8	24.5	26.2	27.9	29.5	31.2	32.8	34.4
82	-	-	-	-	-	-	-	-	-	5.2	7.1	8.9	10.6	12.2	13.7	15.4	17.2	18.9	20.6	22.3	24.0	25.7	27.4	29.1	30.7	32.4	34.0
83	-	-	-	-	-	-	-	-	-	-	6.3	8.2	9.9	11.6	13.1	14.9	16.6	18.4	20.1	21.8	23.5	25.2	26.9	28.6	30.3	32.0	33.7
84	-	-	-	-	-	-	-	-	-	-	5.5	7.4	9.2	10.9	12.5	14.3	16.1	17.8	19.6	21.3	23.0	24.8	26.5	28.2	29.9	31.6	33.3
85	-	-	-	-	-	-	-	-	-	-	-	6.6	8.5	10.3	11.9	13.7	15.5	17.3	19.0	20.8	22.6	24.3	26.0	27.8	29.5	31.2	32.9
86	-	-	-	-	-	-	-	-	-	-	-	5.8	7.8	9.6	11.3	13.2	15.0	16.7	18.5	20.3	22.1	23.8	25.6	27.3	29.1	30.8	32.6
87	-	-	-	-	-	-	-	-	-	-	-	5.0	7.0	8.9	10.6	12.6	14.4	16.2	18.0	19.8	21.6	23.4	25.1	26.9	28.7	30.4	32.2
88	-	-	-	-	-	-	-	-	-	-	-	-	6.3	8.2	10.0	12.0	13.9	15.7	17.5	19.3	21.1	22.9	24.7	26.5	28.3	30.1	31.8
89	-	-	-	-	-	-	-	-	-	-	-	-	5.5	7.5	9.4	11.5	13.3	15.1	17.0	18.8	20.6	22.4	24.3	26.1	27.9	29.7	31.5
90	-	-	-	-	-	-	-	-	-	-	-	-	-	6.8	8.8	10.9	12.8	14.6	16.5	18.3	20.1	22.0	23.8	25.6	27.5	29.3	31.1

Greyed area indicates test conditions where the return drybulb temperature must exceed 70°F

Table RK-1: Target Superheat (Suction Line Temperature - Evaporator Saturation Temperature) (continued)

	Return Air Wet-Bulb Temperature (°F) ($T_{return, wb}$)																										
Condenser Air Dry-Bulb Temperature (°F)	50	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67	68	69	70	71	72	73	74	75	76
91	-	-	-	-	-	-	-	-	-	-	-	-	-	6.1	8.1	10.3	12.2	14.1	15.9	17.8	19.7	21.5	23.4	25.2	27.1	28.9	30.8
92	-	-	-	-	-	-	-	-	-	-	-	-	-	5.4	7.5	9.8	11.7	13.5	15.4	17.3	19.2	21.1	22.9	24.8	26.7	28.5	30.4
93	-	-	-	-	-	-	-	-	-	-	-	-	-	-	6.8	9.2	11.1	13.0	14.9	16.8	18.7	20.6	22.5	24.4	26.3	28.2	30.1
94	-	-	-	-	-	-	-	-	-	-	-	-	-	-	6.2	8.7	10.6	12.5	14.4	16.3	18.2	20.2	22.1	24.0	25.9	27.8	29.7
95	-	-	-	-	-	-	-	-	-	-	-	-	-	-	5.6	8.1	10.0	12.0	13.9	15.8	17.8	19.7	21.6	23.6	25.5	27.4	29.4
96	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	7.5	9.5	11.4	13.4	15.3	17.3	19.2	21.2	23.2	25.1	27.1	29.0
97	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	7.0	8.9	10.9	12.9	14.9	16.8	18.8	20.8	22.7	24.7	26.7	28.7
98	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	6.4	8.4	10.4	12.4	14.4	16.4	18.3	20.3	22.3	24.3	26.3	28.3
99	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	5.8	7.9	9.9	11.9	13.9	15.9	17.9	19.9	21.9	24.0	26.0	28.0
100	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	5.3	7.3	9.3	11.4	13.4	15.4	17.5	19.5	21.5	23.6	25.6	27.7
101	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	6.8	8.8	10.9	12.9	15.0	17.0	19.1	21.1	23.2	25.3	27.3
102	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	6.2	8.3	10.4	12.4	14.5	16.6	18.6	20.7	22.8	24.9	27.0
103	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	5.7	7.8	9.9	11.9	14.0	16.1	18.2	20.3	22.4	24.5	26.7
104	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	5.2	7.2	9.3	11.5	13.6	15.7	17.8	19.9	22.1	24.2	26.3
105	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	6.7	8.8	11.0	13.1	15.2	17.4	19.5	21.7	23.8	26.0
106	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	6.2	8.3	10.5	12.6	14.8	17.0	19.1	21.3	23.5	25.7
107	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	5.7	7.9	10.0	12.2	14.4	16.6	18.7	21.0	23.2	25.4
108	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	5.2	7.4	9.5	11.7	13.9	16.1	18.4	20.6	22.8	25.1
109	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	6.9	9.1	11.3	13.5	15.7	18.0	20.2	22.5	24.7
110	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	6.4	8.6	10.8	13.1	15.3	17.6	19.9	22.1	24.4
111	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	5.9	8.1	10.4	12.6	14.9	17.2	19.5	21.8	24.1
112	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	5.4	7.6	9.9	12.2	14.5	16.8	19.1	21.5	23.8
113	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	7.2	9.5	11.8	14.1	16.4	18.8	21.1	23.5
114	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	6.7	9.0	11.4	13.7	16.1	18.4	20.8	23.2
115	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	6.2	8.6	10.9	13.3	15.7	18.1	20.5	22.9

Table RK-2: Target Temperature Split (Return Dry-Bulb – Supply Dry-Bulb)

Return Air Dry–Bulb (ºF) ($T_{return, db}$)	Return Air Wet-Bulb (ºF) ($T_{return, wb}$)																										
	50	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67	68	69	70	71	72	73	74	75	76
70	20.9	20.7	20.6	20.4	20.1	19.9	19.5	19.1	18.7	18.2	17.7	17.2	16.5	15.9	15.2	14.4	13.7	12.8	11.9	11.0	10.0	9.0	7.9	6.8	5.7	4.5	3.2
71	21.4	21.3	21.1	20.9	20.7	20.4	20.1	19.7	19.3	18.8	18.3	17.7	17.1	16.4	15.7	15.0	14.2	13.4	12.5	11.5	10.6	9.5	8.5	7.4	6.2	5.0	3.8
72	21.9	21.8	21.7	21.5	21.2	20.9	20.6	20.2	19.8	19.3	18.8	18.2	17.6	17.0	16.3	15.5	14.7	13.9	13.0	12.1	11.1	10.1	9.0	7.9	6.8	5.6	4.3
73	22.5	22.4	22.2	22.0	21.8	21.5	21.2	20.8	20.3	19.9	19.4	18.8	18.2	17.5	16.8	16.1	15.3	14.4	13.6	12.6	11.7	10.6	9.6	8.5	7.3	6.1	4.8
74	23.0	22.9	22.8	22.6	22.3	22.0	21.7	21.3	20.9	20.4	19.9	19.3	18.7	18.1	17.4	16.6	15.8	15.0	14.1	13.2	12.2	11.2	10.1	9.0	7.8	6.6	5.4
75	23.6	23.5	23.3	23.1	22.9	22.6	22.2	21.9	21.4	21.0	20.4	19.9	19.3	18.6	17.9	17.2	16.4	15.5	14.7	13.7	12.7	11.7	10.7	9.5	8.4	7.2	5.9
76	24.1	24.0	23.9	23.7	23.4	23.1	22.8	22.4	22.0	21.5	21.0	20.4	19.8	19.2	18.5	17.7	16.9	16.1	15.2	14.3	13.3	12.3	11.2	10.1	8.9	7.7	6.5
77	-	24.6	24.4	24.2	24.0	23.7	23.3	22.9	22.5	22.0	21.5	21.0	20.4	19.7	19.0	18.3	17.5	16.6	15.7	14.8	13.8	12.8	11.7	10.6	9.5	8.3	7.0
78	-	-	-	24.7	24.5	24.2	23.9	23.5	23.1	22.6	22.1	21.5	20.9	20.2	19.5	18.8	18.0	17.2	16.3	15.4	14.4	13.4	12.3	11.2	10.0	8.8	7.6
79	-	-	-	-	-	24.8	24.4	24.0	23.6	23.1	22.6	22.1	21.4	20.8	20.1	19.3	18.5	17.7	16.8	15.9	14.9	13.9	12.8	11.7	10.6	9.4	8.1
80	-	-	-	-	-	-	25.0	24.6	24.2	23.7	23.2	22.6	22.0	21.3	20.6	19.9	19.1	18.3	17.4	16.4	15.5	14.4	13.4	12.3	11.1	9.9	8.7
81	-	-	-	-	-	-	-	25.1	24.7	24.2	23.7	23.1	22.5	21.9	21.2	20.4	19.6	18.8	17.9	17.0	16.0	15.0	13.9	12.8	11.7	10.4	9.2
82	-	-	-	-	-	-	-	-	25.2	24.8	24.2	23.7	23.1	22.4	21.7	21.0	20.2	19.3	18.5	17.5	16.6	15.5	14.5	13.4	12.2	11.0	9.7
83	-	-	-	-	-	-	-	-	-	25.3	24.8	24.2	23.6	23.0	22.3	21.5	20.7	19.9	19.0	18.1	17.1	16.1	15.0	13.9	12.7	11.5	10.3
84	-	-	-	-	-	-	-	-	-	25.9	25.3	24.8	24.2	23.5	22.8	22.1	21.3	20.4	19.5	18.6	17.6	16.6	15.6	14.4	13.3	12.1	10.8

Appendix RL – Forced Air System Fan Flow and Air Handler Fan Watt Draw

NOTE: THIS APPENDIX IS ENTIRELY NEW SO FOR CLARITY, NO UNDERLINES ARE SHOWN.

RL1. Purpose and Scope

ACM RL contains procedures for verifying adequate airflow in split system and packaged air conditioning systems serving low-rise residential buildings. The procedure is also used to calculate a credit for improved air distribution design, including more efficient motors and air distribution systems with fewer obstructions.

RL2. Instrumentation Specifications

The instrumentation for the air distribution diagnostic measurements shall conform to the following specifications:

RL2.1 Pressure Measurements

All pressure measurements shall be measured with measurement systems (i.e., sensor plus data acquisition system) having an accuracy of ± 0.2 Pa. All pressure measurements within the duct system shall be made with static pressure probes.

RL2.2 Fan Flow Measurements

All measurements of distribution fan flows shall be made with measurement systems (i.e., sensor plus data acquisition system) having an accuracy of ± 7% reading or ± 5 cfm whichever is greater.

RL2.3 Watt Measurements

All measurements of air handler watt draws shall be made with measurement systems (i.e., sensor plus data acquisition system) having an accuracy of ± 1% reading or ± 5 watts whichever is greater.

RL3. Apparatus

RL3.1 System Fan Flows

HVAC system fan flow shall be measured using one of the following methods.

RL3.1.1 Plenum Pressure Matching Measurement

The apparatus for measuring the system fan flow shall consist of a duct pressurization and flow measurement device (subsequently referred to as a fan flowmeter) meeting the specifications in 2.2, a static pressure transducer meeting the specifications in Section 2.1, and an air barrier between the return duct system and the air handler inlet. The measuring device shall be attached at the air handler blower compartment door. All registers shall be in their normal operating condition. The static pressure probe shall be fixed to the supply plenum so that it is not moved during this test.

RL3.1.2 Flow Capture Hood Measurement

A flow capture hood meeting the specifications in Section 2.2 can be used to verify the fan flow at the return register(s). All registers shall be in their normal operating position. Measurement(s) shall be taken at the return grill(s).

RL3.1.3 Flow Grid Measurement

The apparatus for measuring the system fan flow shall consist of a flow measurement device (subsequently referred to as a fan flow grid) meeting the specifications in 2.2 and a static pressure transducer meeting the specifications in Section 2.1. The measuring device shall be attached at a point where all the fan airflow shall flow through the flow grid. All registers shall be in their normal operating condition. The static pressure probe shall be fixed to the supply plenum so that it is not moved during this test.

RL3.2 Air Handler Watts

The air handler watt draw shall be measured using one of the following methods.

RL3.2.1 Portable Watt Meter Measurement

The apparatus for measuring the air handler watt draw shall consist of a watt meter meeting the specifications in X.1.3. The measuring device shall be attached to measure the air handler fan watt draw. All registers shall be in their normal operating condition.

RL3.2.2 Utility Revenue Meter Measurement

The apparatus for measuring the air handler watt draw shall consist of the utility revenue meter meeting the specifications in X.1.3 and a stopwatch measuring in seconds. All registers shall be in their normal operating condition.

RL4. Procedure

To obtain airflow credit a diagnostic fan flow measurement must be performed and the duct system must be designed.

To obtain airflow and fan watt draw credit. a diagnostic fan flow measurement must be performed, the duct system must be designed, and the air handler fan watt draw measurement must be performed.

RL4.1 Diagnostic Fan Flow

The diagnostic fan flow shall be measured using one of the following methods:

RL4.1.1 Diagnostic Fan Flow Using Flow Capture Hood

The fan flow measurement shall be performed using the following procedures; all registers shall be fully open, and the air filter shall be installed. Turn on the system fan at the maximum speed used in the installation (usually the cooling speed when air conditioning is present) and measure the fan flow at the return grille(s) with a calibrated flow capture hood to determine the total system return fan flow. The system fan flow (Qah, cfm) shall be the sum of the measured return flows.

RL4.1.2 Diagnostic Fan Flow Using Plenum Pressure Matching

The fan flow measurement shall be performed using the following procedures:

1. If the fan flowmeter is to be connected to the air handler outside the conditioned space, then the door or access panel between the conditioned space and the air handler location shall be opened.
2. With the system fan on at the maximum speed used in the installation (usually the cooling speed when air conditioning is present), measure the pressure difference (in pascal) between the supply plenum and the conditioned space (Psp). Psp is the target pressure to be maintained during the fan flow tests. If there is no access to the supply plenum, then place the pressure probe in the nearest supply duct. Adjust the probe to achieve the highest pressure and then firmly attach the probe (e.g., with duct tape) to ensure that it does not move during the fan flow test.3. Block the return duct from the plenum upstream of the air handler fan and the fan flowmeter. Filters are often located in an ideal location for this blockage.
3. Attach the fan flowmeter device to the duct system at the air handler. For many air handlers, there will be a removable section that allows access to the fan that is suitable for this purpose.

4. Turn on the system fan and the fan flow meter, adjust the fan flowmeter until the pressure between supply plenum and conditioned space matches Psp.
5. Record the flow through the flowmeter (Qah, cfm) - this is the diagnostic fan flow. In some systems, typical system fan and fan flowmeter combinations may not be able to produce enough flow to reach Psp. In this case record the maximum flow (Qmax, cfm) and pressure (Pmax) between the supply plenum and the conditioned space. The following equation shall be used to correct measured system flow and pressure (Qmax and Pmax) to operating condition at operating pressure (Psp).

$$\text{Air Handler Flow Qah} = \text{Qmax} \times (\text{Psp}/\text{Pmax})^{.5} \qquad \text{Equation RL1}$$

RL4.1.3 Diagnostic Fan Flow Using Flow Grid Measurement

The fan flow measurement shall be performed using the following procedures:

1. With the system fan on at the maximum speed used in the installation (usually the cooling speed when air conditioning is present measure the pressure difference (in pascal) between the supply plenum and the conditioned space (Psp). If there is no access to the supply plenum, then place the pressure probe in the nearest supply duct. Adjust the probe to achieve the highest pressure and then firmly attach the probe (e.g., with duct tape) to ensure that it does not move during the fan flow test
2. The flow grid shall be attached at a point where all the fan air flows through the flow grid.
3. Re-measure the system operating pressure with the flow grid in place.
4. Measure the air flow through the flow grid (Qgrid) and the test pressure (Ptest).
5. The following equation for air handler flow shall be used to correct flow through the flow grid and pressure (Qgrid and Ptest) to operating condition at operating pressure (Psp).

$$\text{Qah} = \text{Qmax} \times (\text{Psp}/\text{Ptest})^{.5} \qquad \text{Equation RL2}$$

RL4.2 Duct Design

The duct system shall be designed within two constraints, the airflow rate and the available external static pressure from the air handler at that airflow. The duct design shall have calculations showing the duct system will operate at equal to or greater than 0.0375 cfm/Btu rated capacity at ARI test condtions (450 cfm/12000 Btu) in cooling speed (dry coil) or, if heating only, equal to or greater than 16.8 cfm per 1000 Btu/hr furnace output. The design shall be based on the available external static pressure from the air handler, the pressure drop of external devices, the equivalent length of the runs, as well as the size, type and configuration of the ducts. The duct layout shall be included on the plans and the duct design shall be reported on the CF-6R and posted on-site.

RL4.3 Diagnostic Air Handler Watt Draw

The diagnostic air handler watt draw shall be measured using one of the following methods:

RL4.3.1 Diagnostic Air Handler Watt Draw Using Portable Watt Meter

The air handler watt draw measurement shall be performed using the following procedures; all registers shall be fully open, and the air filter shall be installed. Turn on the system fan at the maximum speed used in the installation (usually the cooling speed when air conditioning is present) and measure the fan watt draw (Wfan).

RL4.3.2 Diagnostic Air Handler Watt Draw Using Utility Revenue Meter

The air handler watt draw measurement shall be performed using the following procedures; all registers shall be fully open, and the air filter shall be installed. Turn on the system fan at the maximum speed used in the installation (usually the cooling speed when air conditioning is present) and turn off every circuit breaker except the one exclusively serving the air handler. Record the Kh factor on the revenue meter, count the number of full revolutions of the meter wheel over a period exceeding 90 seconds. Record the number of revolutions (Nrev) and time period (trev, seconds). Compute the air handler watt draw (Wfan) using the following formula:

.

$$\text{Air Handler Fan Watt Draw} \quad \text{Wfan} = (\text{Kh} \times \text{Nrev} \times 3600) / \text{trev} \qquad \text{Equation RL3}$$

Return all circuit breakers to their original positions.

Appendix RM – HVAC Sizing

NOTE: THIS APPENDIX IS ENTIRELY NEW, SO FOR CLARITY, NO UNDERLINES ARE SHOWN.

RM1. Purpose and Scope

ACM RM-2005 is a procedure for calculating the cooling load in low-rise residential buildings (Section RM2) and for determining the maximum allowable cooling load permitted by the standards (Section RM3). Section RM4 has a procedure for determining compliance for oversized equipment by showing that the peak power is equal to or less than equipment that minimally met the requirements of the standard.

RM2. Procedure for Calculating Design Cooling Capacity

The following rules apply when calculating the design cooling capacity as required by Section 150(h)3 of the standards:

RM2.1 Methodology

The methodologies, computer programs, inputs, and assumptions approved by the commission shall be used.

RM2.2 Cooling Loads

Except as specified in this section, calculations will be done in accordance with the method described in Chapter 28, Residential Cooling and Heating Load Calculations, 2001 ASHRAE Fundamentals Handbook. Interpolation shall be used with tables in Chapter 28. The methods in Chapter 29 may not be used under this procedure.

RM2.3 Indoor Design Conditions

The indoor cooling design temperature shall be 75°F. An indoor design temperature swing of 3°F shall be used.

RM2.4 Outdoor Design Conditions

Outdoor design conditions shall be selected from ASHRAE publication SPCDX: Climatic Data for Region X, Arizona, California, Hawaii, and Nevada, 1982 and its supplements. Outdoor cooling design dry bulb temperatures shall be no greater than the temperature listed in the Summer Design Dry Bulb 0.5 percent column.

RM2.5 Block Loads

The design cooling capacity used for calculating the maximum allowable cooling capacity is based on the block (peak) load either for

1. The whole building; or
2. For each zone within a building that is served by its own cooling system; or
3. For each dwelling unit within a building that is served by its own cooling system.

Room-by-room loads are not allowed for calculating the design cooling capacity.

RM2.6 Table Selection

Tables 2 (cooling load temperature differences) and 4 (glass load factors) shall be used for:

1. Buildings with more than one dwelling unit using whole building block loads; or
2. Buildings or zones with either east or west exposed walls but not both east and west exposed walls.

Otherwise, Tables 1 (cooling load temperature differences) and 3 (glass load factors) shall be used.

Note: The table numbers refer to the ASHRAE Fundamentals 2001.

RM2.7 U-factors

U-factors for all opaque surfaces and fenestration products shall be consistent with the methods described in Section 4.2 of the Residential ACM Manual. The effects of radiant barriers or cool roofs shall be included if these features are in the proposed building.

RM2.8 Solar Heat Gain Coefficients

Solar heat gain coefficients (SHGC) shall be equal to the $SHGC_{closed}$ values described in Section 4.4.2 of the Residential ACM Manual.

RM2.9 Glass Load Factors

Glass load factors (GLFs) shall be calculated using the equation in the footnotes of Tables 3 and 4 in Chapter 28 using the columns for “Regular Double Glass” and the rows for “Draperies, venetian blinds, etc”. The table values used in the equation shall be $U_t = 0.55$ and $SC_t = 0.45$. The shading coefficient for the alternate value shall be $SC_a = SHGC \times 0.87$ where the SHGC value is described above. The GLF values shall also be adjusted for latitude as described in the footnotes.

Note: The table numbers refer to the ASHRAE Fundamentals 2001.

RM2.10 Infiltration

The air flow (CFM) due to infiltration and mechanical ventilation shall be calculated with the effective leakage area method as documented in equation 4.19 in Section 4.17.1 of the Residential ACM Manual using the outdoor design temperature minus the indoor design temperature as the temperature difference and a 7.5 mph wind speed.

RM2.11 Internal Gain

Occupancy shall be assumed to be two persons for the first bedroom and one person for each additional bedroom per dwelling unit. Each person shall be assigned a sensible heat gain of 230 Btu/hr. Appliance loads shall be 1200 Btu/hr for multifamily buildings with common floors and ceilings. Otherwise the appliance load is 1600 Btu/hr.

RM2.12 Cooling Duct Efficiency

The cooling duct efficiency shall be calculated using the seasonal approach as documented in ACM RF-2005.

RM2.13 Latent Factor.

The latent factor shall be 1.0.

RM2.14 Total Cooling Load

The total cooling load is calculated in accordance with Table 9 of Chapter 28 with the values specified in this section.

RM2.15 Design Cooling Load

The design cooling load is equal to the total cooling load divided by the cooling duct efficiency.

RM2.16 Design Cooling Capacity

The design cooling capacity calculation adjusts the sensible design cooling load to estimate the rated cooling capacity needed as follows:

- Design Cooling Capacity (Btu/hr) =
- Design Cooling Load (Btu/hr) / (0.88 – (0.002286 x (Outdoor Cooling Design Temperature (°F) – 95)))

RM3. Procedure for Calculating Maximum Allowable Cooling Capacity

The following rules apply when calculating the maximum allowable cooling capacity as required by Section 150(h)3 of the standards:

RM3.1 Design Cooling Capacity

The design cooling capacity shall be calculated in accordance with the procedure described in RM2.

RM3.2 Maximum Allowable Cooling Capacity

For buildings with a single cooling system or for buildings where the design cooling capacity has been calculated separately for each cooling system, the maximum allowable cooling capacity for each cooling system shall be:

Table RM1 – Maximum Allowable Cooling Capacity

Design Cooling Capacity (Btu/hr)		Maximum Allowable Cooling Capacity (Btu/hr)
< 48000		Design Cooling Capacity + 6000
48000 - 60000		Design Cooling Capacity + 12000
>60000		Design Cooling Capacity + 30000

For buildings with more than one cooling system where the design cooling capacity has been calculated for the entire building, the maximum allowable cooling capacity for the entire building shall be:

Maximum Allowable Cooling Capacity (Btu/hr) = Design Cooling Capacity (Btu/hr) + (6000 (Btu/hr) x Number of Cooling Systems) Equation RM1

RM3.3 Multiple Orientations

For buildings demonstrating compliance using the multiple orientation alternative of Section 151(c), the maximum allowable cooling capacity is the highest of the four cardinal orientations. For buildings with more than cooling system, the orientation used for determining the maximum allowable cooling capacity shall be permitted to be different for each zone.

RM4. Procedure for Determining Electrical Input Exception for Maximum Allowable Cooling Capacity

In accordance with the exception to Section 150(h)2, the installed cooling capacity shall be permitted to exceed the maximum allowable cooling capacity if the electrical input of the oversized cooling system is less than or equal to the electrical input of a standard cooling system using the following rules:

RM4.1 Design Cooling Capacity

The design cooling capacity shall be calculated in accordance with the procedure described in RM2.

RM4.2 Standard Total Electrical Input

The standard electrical input is calculated as follows:

Standard Total Electrical Input (W) = 0.117 (W/Btu/hr) x Design Cooling Capacity (Btu/hr) Equation RM2

RM4.3 Proposed Electrical Input

The proposed electrical input (W) for the installed cooling system is published as the “Electrical Input” in the Directories of Certified Appliances maintained by the California Energy Commission in accordance with the requirements of the Appliance Standards.

RM4.4 Proposed Fan Power

The proposed fan power (W) of the installed cooling system is equal to either:

1. 0.017 (W/Btu/hr) x Design Cooling Capacity (Btu/hr); or
2. The measured fan power (W) where the measured fan power is determined using the procedure described in ACM RO of the *Residential ACM Manual*.

RM4.5 Proposed Total Electrical Input

The proposed electrical input is equal to:

Proposed Total Electrical Input (W) = Proposed Electrical Input (W) + Proposed Fan Power (W) Equation RM3

For buildings with more than one cooling system, the proposed total electrical power shall be the sum of the values for each system. If the proposed total electrical input is less than or equal to the standard total electrical input, then the installed cooling capacity may exceed the maximum allowable cooling capacity.

Appendix RN – Water Heating Calculation Method

NOTE: THIS APPENDIX IS ENTIRELY NEW AND UNDERLINES AND STRIKETHROUGHS ARE ELIMINATED FOR CLARITY OF READING.

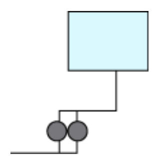
RN1. Purpose and Scope

ACM RN documents the methods and assumptions used for calculating the energy use for residential water heating systems on an hourly basis for both the proposed design and the standard design. The hourly fuel and electricity energy use for water heating will be combined with hourly space heating and cooling energy use to come up with the hourly total fuel and electricity energy use to be factored by the hourly TDV energy multiplier. The calculation procedure applies to low-rise single family, low-rise multi-family, and high-rise residential.

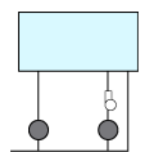
When buildings have multiple water heaters, the hourly total water heating energy use is the hourly water heating energy use summed over all water heating systems, all water heaters, and all dwelling units being modeled.

The following diagrams illustrate some of the cases that are recognized by ACM RM.

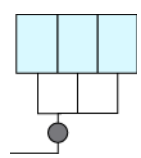
1 One distribution system with two water heaters serving a single dwelling unit.



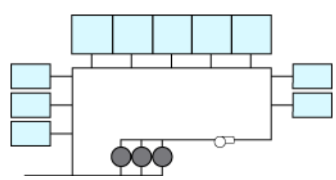
2 Two distribution systems, each with a single water heater serving a single dwelling unit.



3 One distribution system with one water heater serving multiple dwelling units.



4 Single distribution system with multiple water heaters serving multiple units.



The following rules apply to the calculation of water heating system energy use:

- One water heater type per system, e.g. no mix of gas and electric water heaters in the same system
- One solar or woodstove credit (but not both) per system

RN2. Water Heating Systems

Water heating distribution systems may serve more than one dwelling unit and may have more than one piece of water heating equipment. The energy used by a water heating system is calculated as the sum of the energy used by each individual water heater in the system. Energy used for the whole building is calculated as the sum of the energy used by each of the water heating systems. To delineate different water heating elements several indices are used.

i Used to describe an individual dwelling unit. For instance CFAi would be the conditioned floor area of the ith dwelling unit. "N" is the total number of dwelling units.

j Used to refer to the number of water heaters in a system. "M" is the total number of water heaters.

k Used to refer to a water heating system or distribution system. A building can have more than one system and each system can have more than one water heater.

RN3 Hourly Adjusted Recovery Load

The hourly adjusted recovery load (HARL) can be calculated by Equation RN1 through Equation RN7.

$$HARL_k = HSEU_k \times DLM_k \times SSM_k + HRDL_k$$ Equation RN1

This equation calculates the hourly recovery load on the water heater. The hourly adjusted recovery load (HARL) is the heat content of the water delivered at the fixture (HSEU) times the distribution loss multiplier (DLM) times the solar saving multiplier (SSM) plus the hourly recirculation losses between dwelling units (HRDL), which only occurs for multi-family central water heating systems. The DLM will generally be greater than one, which means that heat is wasted as water flows from the water heater to the fixture. The DLM_k is constant for all hours with water heating end use.

$$HSEU_k = 8.345 \times GPH_k \times \Delta T$$ Equation RN2

This equation calculates the hourly standard end use (HSEU) for each hour at all fixtures. The heat content of the water delivered at the fixture is the draw volume in gallons (GPH) times the temperature rise ΔT (difference between the cold water inlet temperature and the hot water supply temperature) times the heat required to elevate a gallon of water 1ºF (the 8.345 constant). GPH are calculated in a manner consistent with the Standard Recovery Load values in the current water heating methodology (see RN3.2.1 Pipe Insulation Eligibility Requirements).

$$DLM_k = 1 + (SDLM_k - 1) \times DSM_k$$ Equation RN3

This is the equation for the distribution loss multiplier. It combines two terms: the standard distribution loss multiplier (SDLM), which depends on the size of the dwelling unit and the number of stories, and the distribution system multiplier (DSM) listed in Table RN2. For point-of-use (POU) distribution systems located in close proximity to all hot water fixtures (see eligibility criteria in RN3.2.1 Pipe Insulation Eligibility Requirements), DLM is equal to one, e.g. there are no distribution losses.

$$SDLM_k = 1.074 + 0.00010 \times CFA_k$$ Equation RN4

This equation gives the standard distribution loss multiplier (SDLM) for one story dwelling units, based on CFA_k (equal to the total CFA divided by the number of water heaters per dwelling unit). Multi-family SDLM's will be calculated based on the one story equation and the average CFA for all units. CFA_k is capped at 2500 ft^2 for all single and multi-family units.

$$SDLM_k = 0.993 + 0.00008 \times CFA_k$$ Equation RN5

This equation gives the standard distribution loss multiplier (SDLM) for two and three story dwelling units, based on CFA_k (equal to the total CFA divided by the number of water heaters per dwelling unit). CFA_k is capped at 2500 ft^2 for all single and multi-family units.

$$SSM_k = 1 - SSF_k \times A \qquad \text{Equation RN6}$$

This equation gives the solar savings multiplier (unitless) for the k^{th} water heating system. The solar savings fraction is determined using ACM RG-2005.

A is the adjustment to the SSF (unitless). A is a value less than 1.0 to account for piping losses when these losses are not accounted for in the f-Chart analysis. A is 1.0 for passive systems (no circulation pump) and systems where piping losses are included in the f-Chart analysis. (Piping loss effects are accounted for in the Commission Passive Solar Credit calculation procedure. Approved ACM compliance supplements shall state that pipe losses are not to be accounted for in the f-Chart analysis of active solar water heating systems[1].

$$\Delta T = T_s - T_{inlet} \qquad \text{Equation RN7}$$

Temperature difference (ºF) between cold water inlet temperature T_{inlet} and the hot water supply temperature T_s.

where

$HARL_k$ = Hourly adjusted recovery load (Btu).

$HSEU_k$ = Hourly standard end use (Btu). This is the amount of heat delivered at the hot water fixtures relative to the cold water inlet temperature.

$HRDL_k$ = Hourly recirculation distribution loss (Btu) is the hot water energy loss in multi-family central water heating recirculation systems (calculated in RN3.4 Hourly Recirculation Distribution Loss for Central Water Heating Systems). HRDL is 0 for all single family water heating systems and for multi-family systems with individual water heaters.

DLM_k = Distribution loss multiplier (unitless).

GPH_k = Hourly hot water consumption (gallons) of the k^{th} system provided in RN3.1 Hourly Hot Water Consumption (GPH).

T_s = Hot water supply temperature of 135ºF.

T_{inlet} = The cold water inlet temperature (ºF) provided in RN3.3 Cold Water Inlet Temperature.

$SDLM_k$ = Standard distribution loss multiplier (unitless). This is calculated using Equation RN4 for single story dwelling units and from Equation RN5 for dwelling units with two or more stories. All multi-family projects utilize Equation RN4 and the average dwelling unit CFA.

DSM_k = Distribution system multiplier (unitless) provided in RN3.2 Distribution System Multiplier (DSM) within the Dwelling Unit.

CFA_k = Conditioned floor area (ft^2) capped at 2500 ft^2 for all single and multi-family units.

When a water heating system has more than one water heater, the total system load is assumed to be shared equally by each water heater. The HARL for the jth water heater is then shown in the following equation.

$$HARL_j = \frac{HARL_k}{NmbrWH_k} \qquad \text{Equation RN8}$$

1 Appendix G of solar water heating is being revised. The changes might affect this section. With the time dependent value analysis method, pumping energy use should be separately accounted for.

where

$NmbrWH_k$ = The number of water heaters in the k^{th} system.

RN3.1 Hourly Hot Water Consumption (GPH)

The average daily hot water consumption GPD for a dwelling unit is equal to 21.5 gallons/day plus an additional 14 gallons per day for each 1000 ft² of conditioned floor area. Consumption is about 31.3 gallons/day for a 700 ft² apartment and 56.5 gallons/day for a 2500 ft² dwelling unit. The equation for daily hot water consumption can be expressed as follows[2]:

$$GPD_i = 21.5 + 0.014 \times CFA_i \qquad \text{Equation RN9}$$

where

GPD_i = Average daily hot water consumption (gallons) of the i^{th} dwelling unit.

CFA_i = Conditioned floor area (ft²) of the i^{th} dwelling unit. When actual conditioned floor area is greater than 2500 ft², 2500 should be used in the above equation.

The hourly water consumption GPH of the k^{th} system is calculated using the average daily hot water consumption and the hourly water consumption schedule for all dwelling units served by the system.

$$GPH_k = \left(\sum_i GPD_i \right) \times SCH_m \qquad \text{Equation RN10}$$

Where

GPH_k = Hourly hot water consumption (gallons) of the k^{th} system.

SCH_m = Fractional daily load for hour "m".

m = Hour of the day.

There are significant variations between hot water usage on weekdays and weekends, and separate schedules are used. The hourly schedules shown in Table RN1 shall be used for calculating the hourly hot water consumption. These data are shown in. These data are used for dwelling units of all types.

2 This equation is derived from the 2001 Residential ACM Approval Manual SRL equation assuming a deltaT of 75ºF (supply temperature of 135ºF and inlet temperature of 60ºF) and 22% distribution losses (0.82 adjustment factor). Hot water use predicted in this equation includes the demand for clothes washers. If multi-family dwellings have a separate laundry facility with a separate water heating system, then 17% of the hot water use predicted by Equation 4.2 should be assigned to the laundry's hot water system and the remaining 83% should be assigned to the dwelling units. The hourly schedule in Table RN1 is used for both the laundry and the dwelling units.

Table RN1 Recommended Water Heating Schedules

Hour	Weekday	Weekend
1	0.014	0.018
2	0.008	0.010
3	0.009	0.009
4	0.011	0.008
5	0.020	0.015
6	0.044	0.023
7	0.089	0.026
8	0.107	0.047
9	0.089	0.077
10	0.066	0.083
11	0.052	0.074
12	0.038	0.061
13	0.036	0.051
14	0.033	0.043
15	0.032	0.039
16	0.026	0.039
17	0.042	0.052
18	0.048	0.058
19	0.052	0.056
20	0.047	0.052
21	0.042	0.047
22	0.039	0.044
23	0.036	0.040
24	0.022	0.028
Sum	1.000	1.000

RN3.2 Distribution System Multiplier (DSM) within the Dwelling Unit

The distribution system multiplier (unitless) is an adjustment for alternative water heating distribution systems within the dwelling unit. A value of one is used for standard distribution systems defined as a “main and branch” piping system with all lines leading from the water heater to the kitchen fixtures insulated to a nominal R-4. Values for alternative distribution systems are given in Table RN2.

Table RN2 Distribution System Multipliers within a Dwelling Unit with one or more Water Heaters

Distribution System Measure	Code	DSM
Pipe Insulation (all lines)	PIA	0.92
Point of Use	POU	0.00
Pipe Insulation (kitchen lines) – Standard Case	PIK	1.00
Parallel Piping	PP	1.09
Recirculation (no control)	RNC	4.81
Recirculation + timer control	RTm	3.22
Recirculation + temperature control	RTmp	3.97
Recirculation + timer/temperature	RTmTmp	2.65
Recirculation + demand control	RDmd	1.39

RN3.2.1 Pipe Insulation Eligibility Requirements

Mandatory Measures for pipe insulation on the first five feet of hot and cold water piping from storage gas water heaters and for pipe insulation for non-recirculation systems on all piping from the water heater to the kitchen fixtures (kitchen sink and dishwasher) as specified in Section 150(j) of Title 24, Part 6.

Pipe insulation credit available if all remaining hot water lines are insulated. Insulation shall meet mandatory minimums in Section 150(j).

RN3.2.2 Point of Use Water (POU) Water Heaters Eligibility Requirements

Current requirements apply. All hot water fixtures in the dwelling unit, with the exception of the clothes washer, must be located within 8' (plan view) of a point of use water heater. To meet this requirement, some houses will require multiple POU units.

RN3.2.3 Recirculation Systems Eligibility Requirements

All recirculation systems must have minimum nominal R-4 pipe insulation on all supply and return recirculation piping. Recirculation systems may not take an additional credit for pipe insulation.

The recirculation loop must be laid out to be within 8 feet (plan view) of all hot water fixtures in the house (with the exception of the clothes washer).

Approved recirculation controls include "no control", timer control, time/temperature control, and demand control. Time/temperature control must have an operational timer initially set to operate the pump no more than 16 hours per day. Temperature control must have a temperature sensor with a minimum 20°F deadband installed on the return line.

Demand recirculation systems shall have a pump (maximum 1/8 hp), control system, and a timer or temperature sensor to turn off the pump in a period of less than 2 minutes from pump activation. Acceptable control systems include push buttons, occupancy sensors, or a flow switch at the water heater for pump initiation. At a minimum, push buttons and occupancy sensors must be located in the kitchen and in the master bathroom.

RN3.2.4 Parallel Piping Eligibility Requirements

Each hot water fixture is individually served by a line, no larger than ½ in., originating from a central manifold located no more than 8 feet from the water heater. Fixtures, such as adjacent bathroom sinks, may be "doubled up" if fixture unit calculation in Table 6-5 of the 1997 Uniform Plumbing Code allow.

Acceptable piping materials include copper and cross-linked polyethylene (PEX), depending upon local jurisdictions.

3/8 in. lines are acceptable, pending local code approval, provided minimum required pressures listed in the 1997 UPC (Section 608.1) can be maintained.

Parallel piping to the kitchen fixtures (dishwasher and sink(s)) must be insulated to comply with the mandatory measure for kitchen line pipe insulation.

RN3.2.5 Overhead plumbing for non-recirculation systems

All plumbing located in attics with a continuous minimum of 4 in. of blown insulation coverage on top of the piping will be allowed to claim the “all lines” pipe insulation credit, provided that:

1. Piping from the water heater to the attic, and
2. Piping in floor cavities or other building cavities are insulated to the minimum required for pipe insulation credit.

RN3.3 Cold Water Inlet Temperature

The water inlet temperature varies monthly by climate zone and is equal to the assumed ground temperature as shown in Table RN3.

Table RN3 Monthly Ground Temperature (ºF)

Climate Zone	Month											
	1	2	3	4	5	6	7	8	9	10	11	12
1	52.2	51.5	51.4	51.8	53.1	54.5	55.6	56.4	56.4	55.8	54.7	53.4
2	53.3	51.5	51.4	52.2	55.6	58.9	61.8	63.6	63.8	62.3	59.5	56.3
3	55.1	54.1	54.0	54.5	56.5	58.5	60.3	61.4	61.5	60.6	58.9	56.9
4	55.5	54.0	53.9	54.6	57.5	60.3	62.8	64.3	64.5	63.2	60.8	58.0
5	55.7	54.8	54.7	55.2	56.9	58.7	60.2	61.1	61.2	60.4	59.0	57.3
6	59.1	58.1	58.0	58.5	60.4	62.4	64.0	65.1	65.2	64.3	62.7	60.8
7	60.1	59.1	59.0	59.5	61.5	63.4	65.2	66.2	66.3	65.5	63.8	61.9
8	60.0	58.8	58.7	59.2	61.6	63.9	66.0	67.3	67.4	66.3	64.3	62.1
9	60.5	59.1	59.0	59.7	62.2	64.8	67.1	68.5	68.6	67.5	65.3	62.8
10	59.4	57.6	57.4	58.3	61.8	65.2	68.2	70.1	70.2	68.7	65.8	62.4
11	54.9	52.4	52.2	53.4	58.2	63.0	67.2	69.8	70.0	67.9	63.8	59.2
12	54.6	52.5	52.3	53.3	57.3	61.3	64.8	67.0	67.2	65.4	62.0	58.1
13	57.5	54.7	54.5	55.8	61.0	66.2	70.6	73.5	73.7	71.4	67.0	62.0
14	54.2	51.2	51.0	52.4	58.2	63.9	68.8	72.0	72.2	69.7	64.8	59.3
15	66.8	64.0	63.8	65.1	70.4	75.8	80.4	83.3	83.6	81.2	76.7	71.5
16	44.4	41.8	41.6	42.8	47.7	52.6	56.8	59.5	59.7	57.5	53.4	48.7

RN3.4 Hourly Recirculation Distribution Loss for Central Water Heating Systems

The distribution losses accounted for in the distribution system multiplier DSM are within each individual dwelling unit. Additional distribution losses occur in most multi-family dwelling units related to recirculation systems between dwelling units. These losses include losses from piping that is or could be part of a recirculation loop and branch piping to individual residential units. These losses are divided into losses to the outside air, the ground and the plenum.

Outside air includes crawl spaces, unconditioned garages, unconditioned equipment rooms, as well as actual outside air. Solar radiation gains are not included in the calculation because the impact of radiation gains is relatively minimal compared to other effects. Additionally, the differences in solar gains for the various conditions (e.g., extra insulation vs. minimum insulation) are relatively even less significant.

The ground condition includes any portion of the distribution piping that is underground, including that in or under a slab. Insulation in contact with the ground must meet all the requirements of Section 150(j), Part 6, of Title 24.

The plenum losses include losses from any distribution system piping that is within the building envelope. This includes distribution system pipes in an attic space, within walls (interior, exterior or between conditioned and unconditioned spaces), within chases on the interior of the building, or within plenum spaces between or above conditioned spaces. It does not include the pipes within the residence. The distribution piping stops at the point where it first meets the boundaries of the apartment.

These losses are added to the load accounted for in the hourly adjusted recovery load HARL, according to Equation RN1 and calculated in the following equation.

$$HRDL_k = NL_{OA} \times UA_{OA} \times (T_s - T_{OA}) + NL_{UG} \times UA_{UG} \times (T_s - T_G) + NL_P \times UA_P \qquad \text{Equation RN11}$$

where

$HRDL_k$ = Hourly recirculation distribution loss (Btu).

T_s = Hot water supply temperature of 135°F.

T_{OA} = Hourly dry-bulb temperature of outside air (°F)

T_G = Hourly ground temperature (°F) assumed constant for each month

NL_{OA} = Normalized load coefficient for outside air term

NL_{UG} = Normalized load coefficient for underground term

NL_P = Normalized load coefficient for plenum term

UA_{OA} = Heat loss rate of circulation pipe exposed to outside air (Btu/hr-°F).

UA_{UG} = Heat loss rate of circulation pipe buried under ground (Btu/hr-°F).

UA_P = Heat loss rate of circulation pipe in plenum (Btu/hr-°F).

The terms UA_{OA}, UA_{UG}, and UA_P represent the conductive area and heat loss rate for the three pipe locations. In each case the UA is a function of the pipe length, pipe diameter and pipe insulation. The program user will need to specify pipe length in each of the three locations, and specify the insulation as being either minimum (as specified in Table 1-G, Section 123, Part 6, of Title 24), or extra. Length and corresponding insulation R-value takeoffs are required for piping in each of the three locations (outdoors, underground, and plenum). Pipe heat loss rates (UA_{OA}, UA_{UG}, and UA_p) are then calculated for use in Equation 4.11.

The normalized load coefficients, NL_{OA}, NL_{UG}, and $NL_{P,}$ are climate zone specific multipliers for the pipe losses to the outside air, ground and plenum, respectively. They are calculated according to the following equations:

$$NL_{OA} = \frac{C_{OA1} \times \exp\left(\frac{C_{OA2} \times UA_{OA}}{0.003154 \times GPD_k}\right)}{WHDH_{OA}} \qquad \text{Equation RN12}$$

$$NL_{UG} = \frac{C_{UG1} \times \exp\left(\frac{C_{UG2} \times UA_{UG}}{0.003154 \times GPD_k}\right)}{WHDH_{UG}} \qquad \text{Equation RN13}$$

$$NL_P = \frac{C_{P1} \times \exp\left(\frac{C_{P2} \times UA_P}{0.003154 \times GPD_k}\right)}{8760} \qquad \text{Equation RN14}$$

where

GPD_k = the hot water consumption per day for the k^{th} system.It is the sum of hot water consumption per day for all dwelling units served by the k^{th} system.

$WHDH_{OA}$ = water heating degree hours based on outside air temperature (hr-°F)

$WHDH_{UG}$ = water heating degree hours based on ground temperature (hr-°F)

C_{OA1}, C_{OA2} = coefficients for outside air pipe loss term (unitless).

C_{UG1}, C_{UG2} = coefficients for underground pipe loss term (unitless).

C_{P1}, C_{P2} = coefficients for plenum pipe loss term (unitless).

Coefficients of C_{OA}, C_{UG}, and C_P vary by climate zones and control schemes of the circulation system. Table RN4 lists values of these coefficients.

Table RN4 Coefficients of C_{OA}, C_{UG} and C_P[3]

Climate Zone	No Controls						Timer Controls					
	C_{OA1}	C_{OA2}	C_{UG1}	C_{UG2}	C_{P1}	C_{P2}	C_{OA1}	C_{OA2}	C_{UG1}	C_{UG2}	C_{P1}	C_{P2}
1	0.5902	-0.0028	0.8323	-0.0029	0.8838	-0.0017	0.5141	-0.0030	0.6717	-0.0030	0.7497	-0.0021
2	0.6149	-0.0028	0.7950	-0.0029	0.8440	-0.0018	0.5387	-0.0030	0.6416	-0.0030	0.7090	-0.0021
3	0.6488	-0.0028	0.7934	-0.0029	0.8424	-0.0018	0.5599	-0.0030	0.6403	-0.0030	0.7124	-0.0021
4	0.6427	-0.0028	0.7787	-0.0029	0.8265	-0.0018	0.5616	-0.0030	0.6285	-0.0030	0.6953	-0.0021
5	0.6656	-0.0029	0.7909	-0.0029	0.8399	-0.0018	0.5748	-0.0031	0.6383	-0.0030	0.7073	0.0021
6	0.6898	-0.0029	0.7539	-0.0029	0.8005	-0.0018	0.5918	-0.0031	0.6084	-0.0030	0.6768	-0.0021
7	0.6925	-0.0029	0.7429	-0.0029	0.7888	-0.0018	0.5972	-0.0030	0.5997	-0.0030	0.6664	-0.0021
8	0.6935	-0.0029	0.7395	-0.0029	0.7850	-0.0018	0.5973	-0.0030	0.5968	-0.0030	0.6611	-0.0021
9	0.6928	-0.0029	0.7314	-0.0029	0.7764	-0.0018	0.5966	-0.0030	0.5902	-0.0030	0.6519	-0.0021
10	0.6876	-0.0029	0.7312	-0.0029	0.7762	-0.0018	0.5938	-0.0030	0.5902	-0.0030	0.6491	-0.0021
11	0.5913	-0.0028	0.7591	-0.0029	0.8054	-0.0018	0.5156	-0.0030	0.6126	-0.0030	0.6763	-0.0021
12	0.6037	-0.0028	0.7730	-0.0029	0.8203	-0.0018	0.5276	-0.0030	0.6239	-0.0030	0.6887	-0.0021
13	0.6346	-0.0028	0.7286	-0.0029	0.7730	-0.0018	0.5522	-0.0030	0.5880	-0.0030	0.6480	-0.0021
14	0.6280	-0.0028	0.7543	-0.0029	0.8002	-0.0018	0.5521	-0.0030	0.6088	-0.0030	0.6703	-0.0021
15	0.7158	-0.0029	0.6307	-0.0029	0.6690	-0.0018	0.6130	-0.0031	0.5090	-0.0030	0.5559	-0.0022
16	0.4965	-0.0028	0.8662	-0.0029	0.9193	-0.0018	0.4410	-0.0030	0.6990	-0.0030	0.7756	-0.0021

Table RN4 provides coefficients for recirculation systems where the pumps are always on and tables for recirculation systems that are shut off during hours 1 through 5, and hours 23 and 24 (from 10p.m. to 5a.m.). There is no set of coefficients provided for the case where the circulation system does not rely on a recirculation pump. Such a system would be unlikely to supply hot water within parameters acceptable to tenants. It can be assumed that any distribution systems for supplying hot water from a central boiler or water heater require a recirculation pump and one would be supplied retroactively if not initially.

$WHDH_{OA}$ is the sum of the differences between the temperature of the supply hot water (135˚F) and the hourly outdoor temperature for all 8760 hours of the year. This term varies by climate zone. The values for this term are listed in Table RN5 below. The equation uses the hourly outdoor temperatures from the weather files incorporated in the CEC approved programs.

$WHDH_{UG}$ is the sum of the differences between the supply hot water temperature (135˚F) and the hourly ground temperature for all 8760 hours of the year. This term varies by climate zone. The appropriate values for this term are listed in Table RN5 below. The equation uses the ground temperatures from the weather files incorporated in the CEC approved programs which are assumed to be stable on a monthly basis.

[3] Coefficient values for other climate zones are to be provided before the November Workshop.

Table RN5 Water Heating Degree Hours for Outside Air and Underground

Climate Zone	**$WHDH_{OA}$ (hr-°F)**	**$WHDH_{UG}$ (hr-°F)**
1	712810	710306
2	680634	678425
3	679350	677026
4	666823	664459
5	677373	674935
6	645603	643236
7	636342	633811
8	633244	630782
9	626251	623822
10	625938	623741
11	649661	647770
12	661719	659676
13	623482	621526
14	645367	643517
15	539736	537782
16	741372	739378

UA terms are calculated using inputs provided by the user and base assumptions about the pipe diameter: The user inputs are:

1. Pipe length in each of the three locations
2. Insulation R value of the pipe in each location

The total length of the circulation pipe is calculated, along with the fraction in each location (PF_{OA}, PF_{UG} and PF_P). The square feet of surface area is calculated according to the following equation:

$$SF_{total} = -202.1 + 6.226 \times NmbrApt + 0.1388 \times LF_{total}$$ Equation RN15

where

SF_{Total} = The total square feet of surface area of the circulation piping,

NmbrApt = The number of apartments in the building, and

LF_{Total} = The total lineal feet of all circulation piping.

Note that this equation provides a reasonable approximation of the area of pipe while avoiding the enforcement problems that would exist by the potentially more accurate approach of asking the user to input the length of pipe of each diameter in each location. Such an approach would rely on data that could not be easily field-verified.

The UA for each of the three locations is derived as a function of the fraction of the total pipe in that location times a factor that represents the conductivity of the standard (minimum) insulation or the “extra” insulation condition. The following two equations provide the alternate equations for the two insulation cases. The factors do not vary by location so the equations for the other two locations are of exactly the same form, varying only by the fraction of pipe in that location.

The benefits of additional insulation shall be calculated as required in Section 150(j) of Title 24. The insulation value of the ground and of protective coverings may not be used for achieving the minimum insulation values required by Section 150(j).

For extra insulation:

$$UA_{OA} = 3.0116 \times SF_{total} \times PF_{OA}$$ Equation RN16

For minimum insulation: $$UA_{OA} = 4.3668 \times SF_{total} \times PF_{OA}$$ Equation RN17

RN3 Energy Use of Individual Water Heaters

Once the hourly adjusted recovery load is determined for each water heater, the energy use for each water heater is calculated as described below.

RN4.1 Storage Gas, Storage Electric and Heat Pump Water Heaters

The hourly energy use of storage gas, storage electric and heat pump water heaters is given by the following equation.

$$WHEU_j = \left[\frac{HARL_j \times HPAF_j}{LDEF_j}\right] WSAF_j$$ Equation RN18

where

$WHEU_j$ = Hourly energy use of the water heater (Btu), adjusted for tank insulation and wood stove boilers.

$HARL_j$ = Hourly adjusted recovery load (Btu).

$HPAF_j$ = Heat pump adjustment factor from the table below based on climate zone. This value is one for storage gas, storage oil and storage electric water heaters.

Table RN6 Heat Pump Adjustment Factors

Climate Zone	Heat Pump Adjustment Factor	Climate Zone	Heat Pump Adjustment Factor
1	1.040	9	0.920
2	0.990	10	0.920
3	0.990	11	0.920
4	1.070	12	1.070
5	1.070	13	0.920
6	0.920	14	1.040
7	0.920	15	0.920
8	0.920	16	1.500

$LDEF_j$ = The hourly load dependent energy factor (LDEF) is given by the following equation. This equation adjusts the standard EF for different load conditions.

$$LDEF_j = e \times \left(\ln\left(\frac{HARL_j \times 24}{1000}\right)(a \times EF_j + b) + (c \times EF_j + d)\right)$$ Equation RN19

a,b,c,d,e = Coefficients from the table below based on the water heater type.

Table RN7 LDEF Coefficients

Coefficient	Storage Gas	Storage Electric	Heat Pump
a	-0.098311	-0.91263	0.44189
b	0.240182	0.94278	-0.28361
c	1.356491	4.31687	-0.71673
d	-0.872446	-3.42732	1.13480
E	0.946	0.976	0.947

EFj = Energy factor of the water heater (unitless). This is based on the DOE test procedure.

WSAFk = Wood stove boiler adjustment factor for the kth water heating system. This is given in Section RN4.5 Wood Stove Adjustment Factors. This is an optional capability and is set to 1.00 for ACMs without wood stove boiler modeling capability.

RN4.2 Instantaneous Gas or Oil

The hourly energy use for instantaneous gas or oil water heaters is given by the following equations.

$$WHEU_{j,fuel} = \frac{HARL_j \times WSAF_j}{EF_j}$$ Equation RN20

$$WHEU_{j,elec} = \frac{PILOT_j \times WSAF_j}{1000}$$ Equation RN21

where

$WHEU_{j,\ fuel}$ = Hourly fuel energy use of the water heater (Btu), adjusted for wood stove boilers.

$WHEU_{j,\ elec}$ = Hourly electricity energy use of the water heater (kWh), adjusted for wood stove boilers.

$HARL_j$ = Hourly adjusted recovery load.

EF_j = Energy factor from the DOE test procedure (unitless). This is taken from manufacturers literature or from the CEC Appliance Database.

$PILOT_j$ = Energy consumption of the pilot light (Watt).

$WSAF_k$ = Wood stove boiler adjustment factor for the k^{th} water heating system. This is an optional capability and is set to 1.00 for ACMs without wood stove boiler modeling capability.

RN4.3 Instantaneous Electric

The hourly energy use for instantaneous electric water heaters is given by the following equation.

$$WHEU_{j,elec} = \frac{HARL_j \times WSAF_j}{3413 \times EF_j}$$ Equation RN22

where

$WHEU_{j,\ elec}$ = Hourly electricity energy use of the water heater (kWh), adjusted for wood stove boilers.

$HARL_j$ = Hourly adjusted recovery load.

EF_j = Energy factor from DOE test procedure (unitless).

$WSAF_k$ = Wood stove boiler adjustment factor for the k^{th} water heating system. This is an optional capability and is set to 1.00 for ACMs without wood stove boiler modeling capability.

RN4.4 Large storage gas and Indirect Gas

Energy use for large storage gas and indirect gas water heaters is given by the following equations. Note: large storage gas water heaters are defined as any gas storage water heater with a minimun input rate of 75,000 Btu/h.

$$WHEU_{j,fuel} = \left[\frac{HARL_j + HJL_j}{EFF_j \times EAF_j}\right] WSAF_j \qquad \text{Equation RN23}$$

$$WHEU_{j,elec} = \frac{PILOT_j \times WSAF_j}{1000} \qquad \text{Equation RN24}$$

where

$WHEU_{j,fuel}$ = Hourly fuel energy use of the water heater (Btu), adjusted for tank insulation and wood stove boilers.

$WHEU_{j,elec}$ = Hourly electricity energy use of the water heater (kWh), adjusted for tank insulation and wood stove boilers.

$HARL_j$ = Hourly adjusted recovery load.

HJL_j = Hourly jacket loss (Btu/h).

EFF_j = Efficiency (fraction, not %). To be taken from CEC Appliance Database or from manufacturers literature. These products may be rated as a recovery efficiency, thermal efficiency or AFUE.

EAF_j = Efficiency adjustment factor (unitless). This value is 1.0 for large storage gas water heaters and 0.98 for indirect gas water heaters.

$PILOT_j$ = Pilot light energy (Watt).

$WSAF_k$ = Wood stove boiler adjustment factor for the k^{th} water heating system. This is an optional capability and is set to 1.00 for ACMs without wood stove boiler modeling capability.

RN4.5 Wood Stove Adjustment Factors

This is an optional capability and the Wood Stove Boiler Adjustment Factor is set to 1.00 for ACMs without wood stove boiler modeling capability. The wood stove adjustment factor (unitless) reduces water heating energy to account for the heat contribution of wood stove boilers. This multiplier is taken from the table below, based on climate zone and whether the wood stove boiler has a recirculation pump. The inclusion of this factor and its relevant input parameters is an optional capability for ACMs. However, when this optional capability is implemented the algorithms and procedures given below must be used.

Table RN8 Wood Stove Adjustment Factors

Climate Zone	Wood Stoves with Pumps	Wood Stoves without Pumps
1	0.775	0.750
2	0.775	0.750
3	0.775	0.750
4	0.865	0.850
5	0.865	0.850
6	0.910	0.900
7	0.910	0.900
8	0.955	0.950
9	0.910	0.900
10	0.955	0.950
11	0.910	0.900
12	0.865	0.850
13	0.910	0.900
14	0.910	0.900
15	1.000	1.000
16	0.730	0.700

RN4.6 Jacket Loss

The hourly jacket loss for large storage gas and indirect gas water heaters is calculated as

$$HJL_j = \frac{TSA_j \times \Delta T}{RTI_j + REI_j} + FTL_j$$

Equation RN25

where

TSA_j = Tank surface area (ft^2).

FTL_j = Fitting losses[4]. This is a constant 61.4 Btu/h.

REI_j = R-value of exterior insulating wrap.

$$RTI_j = \left(\frac{TSA_j \times \Delta T}{(8.345 \times VOL_j \times SBL_j \times \Delta T - FTL_j - 3.413 \times PILOT_j) \times EFF_j \times EAF_j} \right)$$

Equation RN26

SBL_j = Standby loss expressed as a fraction of the heat content of the stored water lost per hour from the CEC Appliance Database or from manufacturer's literature.

$PILOT_j$ = Pilot light power (Watt).

ΔT = Temperature difference between cold water inlet and hot water supply temperature (ºF).

RN4.7 Tank Surface Area

Tank surface area (TSA) is used to calculate the hourly jacket loss (HJL) for large storage gas and indirect gas water heaters. TSA is given in the following equation as a function of the tank volume.

4 See Davis Energy Group report, Section III, Page A-8.

$$TSA_j = e \times (f \times VOL_j^{0.33} + g)^2$$ Equation RN27

Where

VOL_j = Tank capacity (gallons).

e, f, g = Coefficients given in the following table.

Table RN9 Coefficients for Calculating Tank Surface Areas

Coefficient	Storage Gas	Large Storage Gas and Indirect Gas	Storage Electric and Heat Pumps
e	0.00793	0.01130	0.01010
f	15.67	11.8	11.8
g	1.9	5.0	5.0

RN5 Electricity Use for Circulation Pumping

For single-family recirculation systems, hourly pumping energy is fixed as shown in following table.

Table RN10 Single Family Recirculation Energy Use (kWh) by Hour of Day

Hour	Uncontrolled Recirculation	Timer Control	Temperature Control	Timer/Temp Control	Demand Recirculation
1	0.040	0	0.0061	0	0.0010
2	0.040	0	0.0061	0	0.0005
3	0.040	0	0.0061	0	0.0006
4	0.040	0	0.0061	0	0.0006
5	0.040	0	0.0061	0	0.0012
6	0.040	0	0.0061	0	0.0024
7	0.040	0.040	0.0061	0.0061	0.0045
8	0.040	0.040	0.0061	0.0061	0.0057
9	0.040	0.040	0.0061	0.0061	0.0054
10	0.040	0.040	0.0061	0.0061	0.0045
11	0.040	0.040	0.0061	0.0061	0.0037
12	0.040	0.040	0.0061	0.0061	0.0028
13	0.040	0.040	0.0061	0.0061	0.0025
14	0.040	0.040	0.0061	0.0061	0.0023
15	0.040	0.040	0.0061	0.0061	0.0021
16	0.040	0.040	0.0061	0.0061	0.0019
17	0.040	0.040	0.0061	0.0061	0.0028
18	0.040	0.040	0.0061	0.0061	0.0032
19	0.040	0.040	0.0061	0.0061	0.0033
20	0.040	0.040	0.0061	0.0061	0.0031
21	0.040	0.040	0.0061	0.0061	0.0027
22	0.040	0.040	0.0061	0.0061	0.0025
23	0.040	0	0.0061	0	0.0023
24	0.040	0	0.0061	0	0.0015
Annual Total	350	234	53	35	23

Multi-family recirculation systems may have vastly different pump sizings and is therefore calculated based on the installed pump size. The hourly electricity use for pumping (HEUP) water in the circulation loop can be calculated by the hourly pumping schedule and the power of the pump motor as in the following equation.

$$HEUP_k = \frac{0.746 \times PUMP_k \times SCH_{k,m}}{\eta_k}$$

Equation RN28

where

$HEUP_k$ = Hourly electricity use for the circulation pump (kWh).

$PUMP_k$ = Pump brake horsepower (bhp).

η_k = Pump motor efficiency

$SCH_{k,m}$ = Operating schedule of the circulation pump. For 24-hour operation (no controls), the value is always 1. For timer controls, the value is 1 when pump is on and 0 otherwise. The pump is assumed off from 10 p.m. to 5 a.m. and on for the remaining hours.

ACM RQ-2005 – High Quality Insulation Installation Procedures

NOTE: THIS IS AN ENTIRELY NEW APPENDIX. FOR CLARITY, IT IS SHOWN WITH NO UNDERLINES.

RQ1. Purpose and Scope

ACM RQ is a procedure for verifying the quality of insulation installation in low-rise residential buildings. A compliance credit is offered when this procedure is followed by a qualified HERS rater. The procedure and credit applies to wood framed construction in low-rise residential buildings.

RQ2. Terminology

Air Barrier — An air barrier is required in all thermal envelope assemblies to prevent air movement. Insulation, other than foam, is not designed to stop air movement. For insulation installed horizontally, such as in an attic, the insulation must be in substantial contact with the assembly air barrier (usually the ceiling drywall) on one side for it to perform at its rated R-value.

Air-tight — Thermal envelope assemblies (such as wall assemblies) shall be built to minimize air movement. Air movement can move unwanted heat and moisture through or into the assembly. For these procedures air-tight shall be defined as an assembly or air barrier with all openings greater than 1/8 in. caulked, or sealed with expansive or minimally expansive foam.

Compression — Batt insulation may be compressed up to 50% at obstructions such as plumbing vents. Where obstructions would cause the insulation to be compressed greater than 50% insulation shall be cut to fit around the obstruction.

Delaminated — Batts are often split or delaminated to fit around an obstruction. For example when an electrical wire runs through a wall cavity the insulation must still fill the area both in front of the wire and the area behind the wire. This is typically accomplished by delaminating the batt from one end and placing one side of the batt behind the wire and the other in front of the wire. The location of the delamination must coincide with the location of the obstruction. For example if the wire is one third of the distance from the front of the cavity the batt should be delaminated so that two thirds of the batt goes behind the wire and one third in front of the wire.

Draft Stops — Draft stops are installed to prevent air movement between wall cavities, other interstitial cavities - and the attic. They are typically constructed of dimensional lumber blocking, drywall or plywood. Draft stops become part of the attic insulation air barrier and shall be air-tight. Fire stops constructed of mineral fiber insulation cannot serve as draft stops since they are not air-tight.

Friction Fit — Friction fit batts are commonly used. Friction fit batts have enough side-to-side frictional force to hold the batt in place without any other means of attachment.

Gaps — A gap is an uninsulated area at the edge of or between batts. Gaps in insulation are avoidable and are not permitted.

Hard Covers — Hard covers shall be installed above areas where there is a drop ceiling. For example a home with 10 ft ceilings may have an entry closet with a ceiling lowered to 8 ft. A hard cover (usually a piece of plywood) is installed at the 10 ft. level above the entry closet. Hard covers become part of the ceiling air barrier and shall be substantially air-tight.

Net Free-Area — The net free-area of a vent cover is equal to the total vent opening less the interference to air flow caused by the screen or louver. Screened or louvered vent opening covers are typically marked by the manufacturer with the "net free-area." For example a 22.5 in. by 3.5 in. eave vent screen with a total area of 78.75 square inches may have a net free-area of only 45 square inches.

Voids — When batt insulation is pushed too far into a wall stud cavity a void is created between the front of the batt and the drywall. Batts shall be fully lofted and fill the cavity front-to-back. Small voids less than ¾ in. deep on the front or back of a batt shall be allowed as long as the total void area is not over 10% of the batt surface area.

RQ3. Raised Floors and Floors Over Garages

- Batts shall be correctly sized to fit snugly at the sides and ends, but not be so large as to buckle.
- Batts shall be cut to fit properly without gaps. Insulation shall not be doubled-over or compressed.
- Insulation shall be in contact with an air barrier - usually the subfloor.
- On floors that are over garages, or where there is an air space between the insulation and the subfloor, the rim joist shall be insulated.
- Batts shall be cut to butt-fit around wiring and plumbing, or be split (delaminated) so that one layer can fit behind the wiring or plumbing, and one layer fit in front.
- If the insulation is faced, the facing shall be placed toward the living space.
- Insulation shall be properly supported to avoid gaps, voids, and compression.

RQ4. Wall Insulation

RQ4.1. Batt Installation

- Wall stud cavities shall be caulked or foamed to provide a substantially air-tight envelope. Special attention shall be paid to plumbing and wiring penetrations through the top plates, electrical boxes that penetrate the sheathing, and the sheathing seal to the bottom plate.
- Installation shall uniformly fill the cavity side-to-side, top-to-bottom, and front-to-back.
- The batt shall be friction fitted into the cavity unless another support method is used.
- Batt insulation shall be installed to fill the cavity and be in contact with the sheathing on the back and the wallboard on the front - no gaps or voids.
- Non-standard-width cavities shall be filled with batt insulation snuggly fitted into the space.
- Batt insulation shall be cut to butt-fit around wiring and plumbing, or be split (delaminated) so that one layer can fit behind the wiring or plumbing, and one layer fit in front.

RQ4.2 Narrow-Framed Cavities

- Non-standard width cavities shall be filled by batt insulation cut to snuggly fit into the space.
- Narrow spaces (two inches or less) at windows, between studs at the building's corners, and at the intersections of partition walls shall be filled with; batt insulation snuggly fitted into the space, loose fill insulation, or expansive or minimally expansive foam.

RQ4.3 Special Situations

RQ4.3.1 Installations Prior to Exterior Sheathing or Lath

- Hard to access wall stud cavities such as; corner channels, patrician wall intersections, and behind tub/shower enclosures shall be insulated to the proper R-value. This may have to be done prior to the installation of the exterior sheathing or the stucco lath.

RQ4.3.2 Obstructions

- Insulation shall be cut to fit around wiring and plumbing without compression.
- Insulation shall be placed between the sheathing and the rear of electrical boxes and phone boxes.
- In cold climates, where water pipes may freeze (Climate Zones 14 and 16) pipes shall have at least two-thirds of the insulation between the water pipe and the outside. If the pipe is near the outside, as much insulation as possible shall be placed behind the pipe, and no insulation shall be placed between the pipe and the inside.

RQ4.3.3 Rim Joists

- All rim-joists shall be insulated to the same R-Value as the adjacent walls.

RQ4.3.4 Kneewalls and Skylight Shafts

- All kneewalls and skylight shafts shall be insulated to a minimum of R-19.
- The insulation shall be installed without gaps and with minimal compression.
- For steel-framed kneewalls and skylight shafts, external surfaces of steel studs must be covered with batts or rigid foam unless otherwise specified on the CF-1R and documented by a form 3R generated by EZFRAME.
- The house side of the insulation shall be in contact with the drywall or other wall finish.
- The insulation shall be supported so that it will not fall down by either fitting to the framing, stapling in place with minimal compression, or using other support such as netting.

RQ4.3.5 HVAC/Plumbing Closet

- Walls of interior closets for HVAC and/or water heating equipment, that require combustion air venting, shall be insulated to the same R-value as the exterior walls.

RQ4.3.6 Loose Fill Wall Insulation

- The installed density shall be measured by both the insulation installer and the HERS rater to assure that the manufacturer's minimum density requirement has been met.
- The insulation installer shall take one density measurement. The measurement shall be recorded on the CF-6R. Note: In order to receive compliance credit the installed density must be verified by the HERS rater.
- The HERS rater shall take one measurement for every 400 square feet of wall area or three measurements, whichever is greater. The rater shall repair the wall insulation at the sample locations. The rater shall record only the lowest density measurement on the CF-4R.
- Measurements shall be taken in accordance with Insulation Contractors Association of America (ICAA) Technical Bulletin No 17: Evaluation of Installed Loose-Fill Attic Insulation. Loose fill insulation that has been installed with water added shall have its weight adjusted for the measured moisture content. A moisture meter shall be used to determine the percent moisture content of the sample before the sample is removed form the wall cavity. The wet sample weight shall be adjusted, using the equation shown below, to provide the air-dry sample weight.

$$\text{Sample Weight}_{\text{air dry}} = (\text{Weight}_{\text{wet sample}} * 1.08) / ((\text{Moisture Content \%} / 100) + 1) \qquad \text{Equation RQ1}$$

RQ5. Ceiling and Roof Insulation

RQ5.1 Batt Insulation

RQ5.1.1 General Requirements

- Batts shall be correctly sized to fit snugly at the sides and ends.
- Batts shall be installed so that they will be in contact with the air barrier.
- Where necessary, batts shall be cut to fit properly - there shall be no gaps, nor shall the insulation be doubled-over or compressed.
- When batts are cut to fit a non-standard cavity, they shall be snuggly fitted to fill the cavity.
- Batts shall be cut to butt-fit around wiring and plumbing, or be split (delaminated) so that one layer can fit behind the wiring or plumbing, and one layer fit in front.
- For batts that are taller than the trusses, full-width batts shall be used so that they expand to touch each other over the trusses.
- Hard covers or draft stops shall be placed over all drop ceiling areas and interior wall cavities to keep insulation in place and stop air movement. If hard covers or draft stops are missing or incomplete, they shall be completed before insulation is installed.
- Required eave ventilation shall not be obstructed - the net free-ventilation area of the eave vent shall be maintained.
- Insulation shall cover all IC rated lighting fixtures.
- Fixtures that are not IC rated (e.g., halogen lamps, heat lamps) shall to be enclosed in an airtight box that meets fire codes, and the box covered with insulation. If fixtures are not IC rated and not enclosed in such a box, they shall be replaced or boxed before insulation is installed.

RQ5.1.2 Special Situations

RQ5.1.2.1 Rafter Ceilings

- An air space shall be maintained between the insulation and roof sheathing, if necessary to meet local codes.
- Facings and insulation shall be kept away from combustion appliance flues in accordance with flue manufacturers' installation instructions or labels on the flue.

RQ5.1.2.2 HVAC Platform

- Verify that the appropriate batt insulation is placed below any plywood platform or cat-walks for HVAC equipment installation and access.
- Batts shall be installed so that they will be in contact with the air barrier.

RQ5.1.2.3 Attic Access

- Permanently attach rigid foam or a batt of insulation to the access cover using adhesive or mechanical fastener.

RQ5.2. Blown-In Ceiling Insulation

RQ5.2.1 General Requirements

- Baffles shall be placed at eaves or soffit vents to keep insulation from blocking eave ventilation. The required net free-ventilation shall be maintained.
- Hard covers or draft stops shall be placed over all drop ceiling areas and interior wall cavities to keep insulation in place and stop air movement. If hard covers or draft stops are missing or incomplete, they

shall be completed before insulation is completed or the entire drop area shall be filled with blown-in insulation level with the rest of the attic.

- Attic rulers appropriate to the material installed shall be placed around the attic to verify depth: one ruler for every 250 square feet, evenly distributed around the attic and clearly readable from the attic access. The rulers shall be scaled to read inches of insulation or the R-value installed.
- Insulation shall be blown to a uniform thickness throughout the attic with all areas meeting or exceeding the insulation manufacturer's minimum requirements for depth and density.
- Insulation shall go underneath and on both sides of obstructions such as cross-bracing and wiring.
- Insulation shall be applied all the way to the outer edge of the wall top plate.
- Insulation shall cover IC-rated lighting fixtures.
- Fixtures that are not IC rated (e.g., halogen lamps, heat lamps) shall to be enclosed in an airtight box that meets fire codes, and the box covered with insulation. If fixtures are not IC rated and not enclosed in such a box, they shall be replaced or boxed before insulation is completed.
- Insulation shall be kept away from combustion appliance flues in accordance with flue manufacturer's installation instructions or labels on the flue.
- The installed weight-per-square-foot shall be measured by both the insulation installer and the HERS rater to assure that the manufacturer's minimum weight-per-square-foot requirement has been met.
- The insulation installer shall take one weight measurement. The measurement shall be recorded on the CF-6R. Note: In order to receive compliance credit the installed weight must be verified by the HERS rater.
- The HERS rater shall take one weight measurement for every 400 square feet of ceiling area or three measurements, whichever is greater. The rater shall repair the ceiling insulation at the sample locations. The rater shall make every effort not to disturb the insulation except where the samples are taken. One sample shall be taken in the area that appears to have the least amount of insulation. The rater shall record only the lowest weight-per-square-foot measurement on the CF-4R.
- Measurements shall be taken in accordance with Insulation Contractors Association of America (ICAA) Technical Bulletin No 17: Evaluation of Installed Loose-Fill Attic Insulation. Loose fill insulation that has been installed with water added shall have its weight adjusted for the measured moisture content. A moisture meter shall be used to determine the percent moisture content of the sample before the sample is removed for weighing. The wet sample weight shall be adjusted, using the equation shown below, to provide the air-dry sample weight.

$$\text{Sample Weight}_{\text{air dry}} = (\text{Weight}_{\text{wet sample}} * 1.08) / ((\text{Moisture Content \%} / 100) + 1) \qquad \text{Equation RQ2}$$

RQ5.2.2 Special Situations

RQ5.2.2.1 Kneewalls and Skylight Shafts:

- Kneewalls and skylight shafts shall be insulated to a minimum of R-19. If loose fill insulation is used it shall be properly supported with netting or other support material.

RQ5.2.2.2 HVAC Platform

- Pressure-fill the areas under any plywood platform or walks for HVAC equipment installation and access or verify that appropriate batt insulation has been installed.

RQ5.2.2.3 Attic Access

- Permanently attach rigid foam or a batt of insulation that is equal or exceeds the R-value of the insulation on the attic floor to the access cover using adhesive or mechanical fastener.

RQ7. Materials

- Materials shall comply with Uniform Building Code (including, but not limited to, 1997 UBC Section 707) and installed to meet all applicable fire codes.
- Materials shall meet California Quality Standards for Insulating Material, Title 24, Chapter 4, Article 3, listed in the California Department of Consumer Affairs Consumer Guide and Directory of Certified Insulating Materials.
- Materials shall comply with flame spread rating and smoke density requirements of Sections 2602 and 707 of the Title 24, Part 2: all installations with exposed facings must use fire retardant facings which have been tested and certified not to exceed a flame spread of 25 and a smoke development rating of 450. Insulation facings that do not touch a ceiling, wall, or floor surface, and faced batts on the undersides of roofs with an air space between the ceiling and facing are considered exposed applications.
- Materials shall be installed according to manufacturer specifications and instructions.

RQ8. Equipment

- Moisture meter - The moisture meter used to measure the moisture content of insulation shall be a resistance type with contact pins that are a minimum of three inches long. The meter shall be calibrated to a standard wood test specimen and be capable of reading to at least 40% moisture content. The meter shall be calibrated in accordance with the manufacturer's instructions.
- Scales - The scales used to weigh density samples shall be accurate to within +/- 0.005 pounds. Scales shall be calibrated in accordance with manufacture's instructions.

RQ9. R-Value and U-Value Specifications

See CF-1R for minimum R-value requirements; for non-standard assemblies, also see applicable form 3R.

RQ10. Certificates

An Insulation Certificate (IC-1) signed by the insulation installer shall be provided that states that the installation is consistent with the plans and specifications for which the building permit was issued. The certificate shall also state the installing company name, insulation manufacturer's name and material identification, the installed R-value, and, in applications of blown-in insulation, the minimum installed weight-per-square-foot (or the minimum weight per cubic foot) consistent with the manufacturer's labeled installed-design-density for the desired R-Value, and the number of inches required to achieve the desired R-Value.

RQ11. Certificate Availability

The Insulation Certificate (IC-1) and Installation Certificate (CF-6R), signed by the insulation installer, shall be available on the building site for each of the HERS rater's verification inspections. Note: The HERS rater cannot verify compliance credit without these completed forms.

CF-6R & CF-4R Insulation Installation Quality Certificate

NOTE: THE FOLLOWING FORM IS PROVIDED FOR INFORMATION. IT WILL LIKELY BE INCLUDED IN THE RESIDENTIAL CONSERVATION MANUAL AND NOT IN THE ACM MANUAL.

Site Address____ Permit ___________

☐ Installation meets all applicable requirements as specified in the Insulation Installation Procedures

(CF-6R only)

☐ Insulation certificate, (IC-1) signed by the installer stating: insulation manufacturer’s name, material identification, installed R-values, and for blown-in insulation: minimum weight per square foot and minimum inches

- ☐ Installation Certificate, (CF-6R) signed by the installer certifying that the installation meets all applicable requirements as specified in the Insulation Installation Procedures

(CF-4R only)

1. FLOOR

- ☐ All floor joist cavity insulation installed to uniformly fit the cavity side-to-side and end-to-end
- ☐ Insulation in contact with the subfloor or rim joists insulated
- ☐ Insulation properly supported to avoid gaps, voids, and compression

2. WALLS

- ☐ Wall stud cavities caulked or foamed to provide an air tight envelope
- ☐ Wall stud cavity insulation uniformly fills the cavity side-to-side, top-to-bottom, and front-to-back
- ☐ No gaps
- ☐ No voids over 3/4" deep or more than 10% of the batt surface area.
- ☐ Hard to access wall stud cavities such as; corner channels, wall intersections, and behind tub/shower enclosures insulated to proper R-Value
- ☐ Small spaces filled
- ☐ Rim-joists insulated
- ☐ Loose fill wall insulation meets or exceeds manufacturer's minimum density requirement. Sample density ______________________ (pounds per cubic foot - air dry or pounds per square foot - air dry). Manufacturer's minimum required density _______________________ (pounds per cubic foot or pounds per square foot). Note: In order to receive compliance credit the HERS rater shall verify that the manufacturer's minimum density has been achieved. (CF-6R only)
- ☐ Loose fill wall insulation meets or exceeds manufacturer's minimum density requirement. Record only lightest sample. Sample density ______________________ (pounds per cubic foot - air dry or pounds per square foot - air dry). Manufacturer's minimum required density _______________________ (pounds per cubic foot or pounds per square foot). (CF-4R only)

3. CEILING PREPARATION

- ☐ All draft stops in place
- ☐ All drops covered with air-tight hard covers
- ☐ Floor cavities on multiple-story buildings have air tight draft stops to all adjoining attics
- ☐ Eave vents prepared for blown insulation - maintain net free-ventilation area
- ☐ Kneewalls insulated or prepared for blown insulation
- ☐ Area under equipment platforms and cat-walks insulated or accessible for blown insulation

4. CEILING BATTS

- ☐ No gaps

☐ No voids over ¾ in. deep or more than 10% of the batt surface area.

☐ Insulation in contact with the air-barrier

☐ Net free-ventilation area maintained at eave vents

5. CEILING BLOWN-IN

☐ Insulation uniformly covers the entire ceiling (or roof) area from the outside of all exterior walls.

☐ Baffles installed at eaves vents or soffit vents - maintain net free-ventilation area of eave vent

☐ Attic access insulated

☐ IC-rated recessed light fixtures covered

☐ Insulation at proper depth – insulation rulers visible and indicating proper depth

☐ Loose fill ceiling insulation meets or exceeds manufacturer's minimum weight requirement for the target R-value. Target R-value ___________________ Manufacturer's minimum required weight for the target R-value ____________________ (pounds per square foot). Sample weight _______________________ (pounds per square foot - air dry). Note: In order to receive compliance credit the HERS rater shall verify that the manufacturer's minimum weight has been achieved for the target R-value. (CF-6R only)

☐ Loose fill ceiling insulation meets or exceeds manufacturer's minimum weight requirement for the target R-value. Record only lightest sample. Target R-value _______________________ Manufacturer's minimum required weight for the target R-value ________________________ (pounds per square foot). Sample weight _______________________ (pounds per square foot - air dry). (CF-4R only)

DECLARATION

I hereby certify that the installation meets all applicable requirements as specified in the Insulation Installation Procedures.

__________	____________________________	____________________________
Item #s	Signature, Date	Title, Company Name
__________	____________________________	____________________________
Item #s	Signature, Date	Title, Company Name
__________	____________________________	____________________________
Item #s	Signature, Date	Title, Company Name